2.5 ON BOARD NOISE ECM

The objective of ECM noise jamming is to deny, delay, or degrade a threat system radar's acquisition or tracking capability. The jamming can be either simple, high power signals that mask the target with "noise" signals, or deceptive countermeasures that create false targets to confuse the radar or that disrupt the range, angle or velocity and introduce tracking errors which can cause a missile to miss the intercept beyond its lethal radius.

ESAMS 2.7 models several on board noise techniques against some of the threat systems contained in ESAMS. The techniques currently modeled in ESAMS are continuous noise, swept spot noise (SSN) and bin masking.

Bin Masking

Bin Masking jamming is used to deny or delay target acquisition by threat radars that employ constant false alarm rate (CFAR) systems for target detection. Fixed detection thresholds worked well enough in the past where the targets had a fairly large RCS, and the threshold could be made large enough that noise interference would not cause false alarms. Low RCS targets, however will generate returns that may slip under a high detection threshold, and lowering the threshold may cause a higher false alarm rate. The function of CFAR systems is to determine if a target exists at a particular range/Doppler bin by checking to see if a signal threshold, adjusted to the noise environment, is exceeded in the bin of interest. With this approach any cell in the range/Doppler matrix that has a signal exceeding the threshold causes a detection.

The detection threshold for the bin being monitored is adjusted to a constant false alarm rate by sampling the power in a selected number of other nearby bins. The threshold is then set by summing the power in the sampled bins and multiplying by a factor that is a function of the probability of false alarm and the number of bins sampled.

If noise is injected into the bins that are used to set the detection threshold for the bin in which the target aircraft resides, then it is possible to raise the threshold to a level that exceeds the target signal return. The target aircraft will either go undetected or the detection will be delayed for a significant period of time until the target is close enough so the signal is high enough to exceed the threshold. Additionally, it may also be possible to insert noise in certain bins so that false targets are presented to the system. This may cause confusion and uncertainty.

Continuous Noise

A less sophisticated, but more robust, technique is barrage or continuous noise jamming. The purpose of this technique is to deny or delay target detection by propagating broadband noise to fill up the entire PRI of the victim radar, causing the target to be lost in the noise signal. Unlike bin masking, continuous noise jamming can be used against either the acquisition mode or the track mode of the threat radar. Thus it can be used to deny or delay acquisition by a threat radar employing a fixed threshold system, and it can be used to degrade missile performance by interfering with tracking data. During noise jamming, the jam signal is added to the target signal and if a threshold is exceeded there is a detection. For continuous noise, the jamming will usually provide a strobe on a plan position indicator (PPI) screen, masking the target's range, but allowing rough angle information.

Swept Spot Noise

The last category of noise jamming in ESAMS is SSN. With this technique, the jamming energy is narrowly focused in frequency thereby not spreading the available energy over a large bandwidth and decreasing the energy seen by the receiver. The focused energy is moved rapidly over the selected frequency range. This has the advantage of concentrating the jam energy in a small bandwidth at any given time and resulting in increased power into the jammed radar. This technique permits the jammer to cover a larger bandwidth, but still put enough power into the radar to be effective. This is particularly necessary with some modern frequency agile radars that continuously change their operating frequency jumping rapidly from one frequency to the next. The SSN signals enter the sum and difference channels and affect tracking.

2.5.1 Functional Element Design Requirements

This section contains the design requirements necessary to implement the on-board noise ECM simulation.

a. ESAMS will simulate the bin masking jamming noise introduced into the range/Doppler bins of target acquisition radars. This noise is passed on to the signal processing functional area in ESAMS which resets the detection threshold setting in CFAR radars.

   The complex voltage over time from the bin masking jammer will be calculated for each of the range/Doppler bins being jammed by the bin masking jammer using standard radar equation derivations. Matrices of these values will be passed on as noise to be used in the signal processing functional area in ESAMS.

b. ESAMS will simulate the continuous noise jamming introduced into the receiver of target acquisition, tracking, missile seeker and fuze sensors.

   Jamming voltage amplitude from the jammer will be calculated for the receiver's sum, azimuth difference, and elevation difference channels using stochastic variables drawn from gaussian and uniform distributions giving the jamming voltage a noise-like representation. This noise is passed on to the signal processing functional area of ESAMS.

c. ESAMS will simulate the swept spot jamming noise introduced into the receiver of target acquisition radars. This noise is passed on to the signal processing functional area in ESAMS.

   The complex voltage over time from the swept spot jammer will be calculated for the radar receiver's sum, azimuth difference, and elevation difference channels using standard radar equation derivations. Matrices of these values will be passed as noise to be used in the signal processing functional area in ESAMS.

2.5.2 Functional Element Design Approach

This section describes the design approach that satisfies the requirements specified in the previous section. The discussion will address specific design approaches of bin masking, continuous noise, and SSN techniques.

Bin Masking and SSN

The design requirements for bin masking and SSN are essentially identical except that different jammer technique characteristics are read in from the jammer tables, and the resulting voltages impact the jammed radar differently.

The design requirements for both types of jamming are addressed by calculating the complex voltages introduced into the victim radar receiver using standard radar calculations and tables of the characteristics of the jamming.

The design approach consists of determining the location, orientation, and velocities of the jammer and victim radar antennas, reading in the characteristics of the jamming signal and jammed radar, and calculating the jamming complex voltages at the radar receiver in the sum, azimuth difference and elevation difference channels. Bin masking concerns mainly sum channel voltages in each of the range doppler bins, while the SSN technique concerns jamming voltages entering both sum and difference channels.

Design Element 5-1: Geometry

This portion of the design addresses the range and relative velocities between the jammer and target radar. These are used to calculate returned Doppler, power and phase.

The following algorithms are used to represent the jammer position relative to the jammed radar in the inertial coordinate system (ICS).

The following equation calculates the closing velocity between the jammer and the radar.

$$V_c = \frac{(\vec{V}_R - \vec{V}_J) \quad (\vec{R}_J - \vec{R}_R)}{\left|\vec{R}_J - \vec{R}_R\right|} \qquad [2.5\text{-}1]$$

where:

$\vec{R}_R$	is the position vector of the radar receiver
$\vec{R}_J$	is the position vector of the jammer
$\vec{V}_R$	is the velocity vector of the radar receiver
$\vec{V}_J$	is the velocity vector of the jammer

The following equations calculate the antenna pointing angles from the jammer antenna to the victim radar. The calculations are used to lookup the proper antenna gain from the antenna gain tables.

$$EL = \sin^{-1}\frac{VZ_{JR}}{R} \qquad [2.5\text{-}2]$$

or

$$EL_e = \tan^{-1}\frac{VZ_{JV}}{R_{XY}}$$

$$AZ = \tan^{-1}\frac{VY_{JV}}{VX_{JV}} \qquad [2.5\text{-}3]$$

where

EL	=	Elevation angle from antenna boresite to victim radar
AZ	=	Azimuth angle from antenna boresite to victim radar
VX_{JV}	=	z vector component antenna to victim radar
VY_{JV}	=	y vector component antenna to victim radar
VX_{JV}	=	x vector component antenna to victim radar
R_{XY}	=	Range in the XY plane antenna to victim radar

Design Element 5-2: Doppler

The Doppler shift due to jammer and victim radar velocity is defined as (Ref. 27):

$$f_d = \frac{-V_C}{\lambda} \qquad [2.5\text{-}4]$$

where λ is the transmitter wavelength and V_J is the closing speed between the jammer and radar:

$$V_C = \frac{(\vec{V}_R - \vec{V}_J) \quad (\vec{R}_J - \vec{R}_R)}{\left|\vec{R}_J - \vec{R}_R\right|}$$

Design Element 5-3: Phase

The following equation calculates the phase at the jammer or radar receiver due to slant range from the jammer to the victim radar:

$$\varphi = 2\pi\frac{\mathrm{mod}(R,\lambda)}{\lambda} \qquad [2.5 - 5]$$

where

φ	=	phase at receiver
R	=	slant range

Design Element 5-4: Power

The power at the receiver's antenna (either jammer or radar), and the sensed power at the receiver are given by: (Ref. 27).

$$P_D = \frac{P_T G_T}{4\pi R^2} \quad [2.5-6]$$

where P_D = power density at the receiving antenna
P_T = transmitter power
G_T = transmitter antenna gain in direction of receiver,

and

$$P_S = \frac{P_T G_T G_R \lambda^2}{(4\pi)^2 R^2} \quad [2.5-7]$$

where P_S = sensed power at the receiver
G_R = victim receiver antenna gain in the direction of the jammer.

Design Element 5-5: Jammer Sensed Voltages and Gains

The following equations provide the voltage to the sum channel, and gain to the azimuth and elevation difference channels of the jammer receiver:

$$V_{\Sigma J} = \frac{\sqrt{P_T G_T G_\Sigma(\theta, \varphi)\lambda^2}}{4\pi R}$$
$$V_{\Delta aJ} = \frac{\sqrt{P_T G_T G_{\Delta a}(\theta, \varphi)\lambda^2}}{4\pi R} \quad [2.5-8]$$
$$V_{\Delta eJ} = \frac{\sqrt{P_T G_T G_{\Delta e}(\theta, \varphi)\lambda^2}}{4\pi R}$$

where $V_{\Sigma J}$ = radar voltage to the jammer receiver's sum channel
$V_{\Delta aJ}$ = radar voltage to the jammer receiver's azimuth difference channel
$V_{\Delta eJ}$ = radar voltage to the jammer receiver's elevation difference channel
$G_{\Sigma(\theta,\varphi)}$ = jammer sum channel voltage gain at angle θ, φ
$G_{\Delta A(\theta,\varphi)}$ =jammer azimuth difference channel gain at angle θ, φ
$G_{\Delta e(\theta,\varphi)}$ =jammer elevation difference channel at angle θ, φ

Design Element 5-6: Jamming Waveform for Repeater (Relative) Jammers

The following equations calculate the waveform transmitted to the victim radars for repeater type jammers.

Doppler frequency: $f_{TJ} = f_d + f_J$ [2.5-9]

where: f_d = Doppler sensed at the jammer
f_J = jammer added doppler shift

Power: $P_{TJ} = P_D P_J \sigma$ [2.5-10]

where:
P_D = power density at the jammer
P_J = jammer power
σ = jammer aircraft RCS

Phase: $\varphi_{TJ} = \varphi + \varphi_J$ [2.5-11]

where:
φ = phase at jammer
φ_J = jammer phase shift

Pulse width: $PW_{TJ} = PW + PW_J$ [2.5-12]

where:
PW = radar pulse width
PW_J = jammer pulse width change

Time delay: $TD_{TJ} = (PW)TD_J$ [2.5-13]

where:
TD_J = jammer time delay

Design Element 5-7: Complex Waveforms at Radar

The complex voltages for the jamming waveform are given by:

$$V_{\Sigma J} = \frac{\sqrt{P_{TJ} G_J G_\Sigma(\theta, \varphi)\lambda^2}}{4\pi R L_R} exp[2\pi i mod(R, \lambda)/\lambda]$$

$$V_{\Delta aJ} = \frac{\sqrt{P_{TJ} G_J G_{\Delta a}(\theta, \varphi)\lambda^2}}{4\pi R L_R} exp[2\pi i mod(R, \lambda)/\lambda] \quad [2.5\text{-}14]$$

$$V_{\Delta eJ} = \frac{\sqrt{P_{TJ} G_J G_{\Delta e}(\theta, \varphi)\lambda^2}}{4\pi R L_R} exp[2\pi i mod(R, \lambda)/\lambda]$$

Where
$V_{\Sigma J}$ = jammer complex voltage to the sum channel
$V_{\Delta aJ}$ = jammer complex voltage to the azimuth difference channel
$V_{\Delta eJ}$ = jammer complex voltage to the elevation difference channel
L_R = radar correction loss factor
$G_\Sigma(\theta,\varphi)$ = radar sum channel voltage gain at angle θ,φ
$G_{\Delta a}(\theta,\varphi)$ = radar azimuth difference channel voltage gain at angle θ,φ
$G_{\Delta e}(\theta,\varphi)$ = radar elevation difference channel voltage gain at angle θ,φ
$exp[2\pi i mod(R, \lambda)/\lambda]$ = the complex number for the phase

Design Element 5-8: Adjust Power Levels

The following equations adjust the jammer voltages to be within the maximum power of the jammer. The total power for all ECM techniques in use are summed. A ratio is developed using the square root of maximum jammer power and all jam wave form voltages are adjusted so the total power does not exceed the jammer maximum power.

$$R_V = \sqrt{\frac{P_{MAX}}{P_{SUM}}} \tag{2.5-15}$$

Where R_V = ratio to adjust jamming technique voltage
P_{MAX} = maximum jammer power
P_{SUM} = the sum of all calculated jammer technique powers

$$\begin{aligned} V_{\Sigma JA} &= V_{\Sigma J} R_V \\ V_{\Delta aJA} &= V_{\Delta aJ} R_V \\ V_{\Delta eJA} &= V_{\Delta eJ} R_V \end{aligned} \tag{2.5-16}$$

Where $V_{\Sigma JA}$ = adjusted jammer complex voltage to the sum channel
$V_{\Delta aJA}$ = adjusted jammer complex voltage to the azimuth difference channel
$V_{\Delta eJA}$ = adjusted jammer complex voltage to the elevation difference channel

Continuous Noise

The design requirements for continuous noise jamming are addressed by calculating the voltages in the sum, azimuth difference, and elevation difference channels of the victim radar using standard radar range calculations and tables of the characteristics of the jamming, and giving these voltages a noise like quality.

The design approach consists of determining the location, orientation, and velocities of the jammer and victim radar antennas, reading in the characteristics of the jamming signal and jammed radar, calculating the voltages in the sum, azimuth difference, and elevation difference channels, and, developing the amplitude of the continuous noise using a stochastic variable drawn from a gaussian distribution giving the jamming voltage a noise-like representation. The geometry, power, and sensed jamming voltages are calculated using the same methodology described above for bin masking.

Design Element 5-9: Continuous Noise Amplitude Calculation

The following equations calculate the stochastic noise amplitude modulations.

$$
\begin{aligned}
VR_{\Sigma J} &= V_{\Sigma J} U_G e^{i2\pi U_u} \\
VR_{\Delta aJ} &= V_{\Delta aJ} U_G e^{i2\pi U_u} \\
VR_{\Delta eJ} &= V_{\Delta eJ} U_G e^{i2\pi U_u}
\end{aligned}
\qquad [2.5\text{-}17]
$$

where $VR_{\Delta J}$, $VR_{\Delta aJ}$, and $VR_{\Delta eJ}$ = stochastic, complex noise jamming voltages put into the radar receiver's sum, azimuth difference and elevation difference channels.

U_G = a random Gaussian variable with zero mean and σ equal to the noise voltage magnitude.

U_u = variable from a uniform distribution between zero and one.

2.5.3 Functional Element Software Design

This section describes the software design necessary to implement the functional element requirements and the design approach outlined above. Section 2.5.3 is organized as follows: the first part describes the subroutine hierarchy and gives descriptions of the relevant subroutines; the second part contains functional flow charts for the functional element as a whole and describes the major operations represented by each block in the charts; the third part presents detailed logical flow charts for the subroutines; and the last part contains a description of all input and output for the functional element as a whole and for each subroutine that implements the functional element.

ECM On-Board Noise Subroutine Hierarchy

The FORTRAN call tree for the ECM On-Board Noise Functional Element in the ESAMS 2.7 computer code is shown in Figure 2.5-1. The diagram depicts the entire model structure from the top level ZINGER (the Main subprogram) through all the routines allocated to the functional element. Subroutines allocated directly to the implementation of the functional element are shown with a heavy-line box. Subroutines which use functional element results are shown with a medium-line box. The subroutines allocated to the functional element are listed in Table 2.5-1, together with brief descriptions of them.

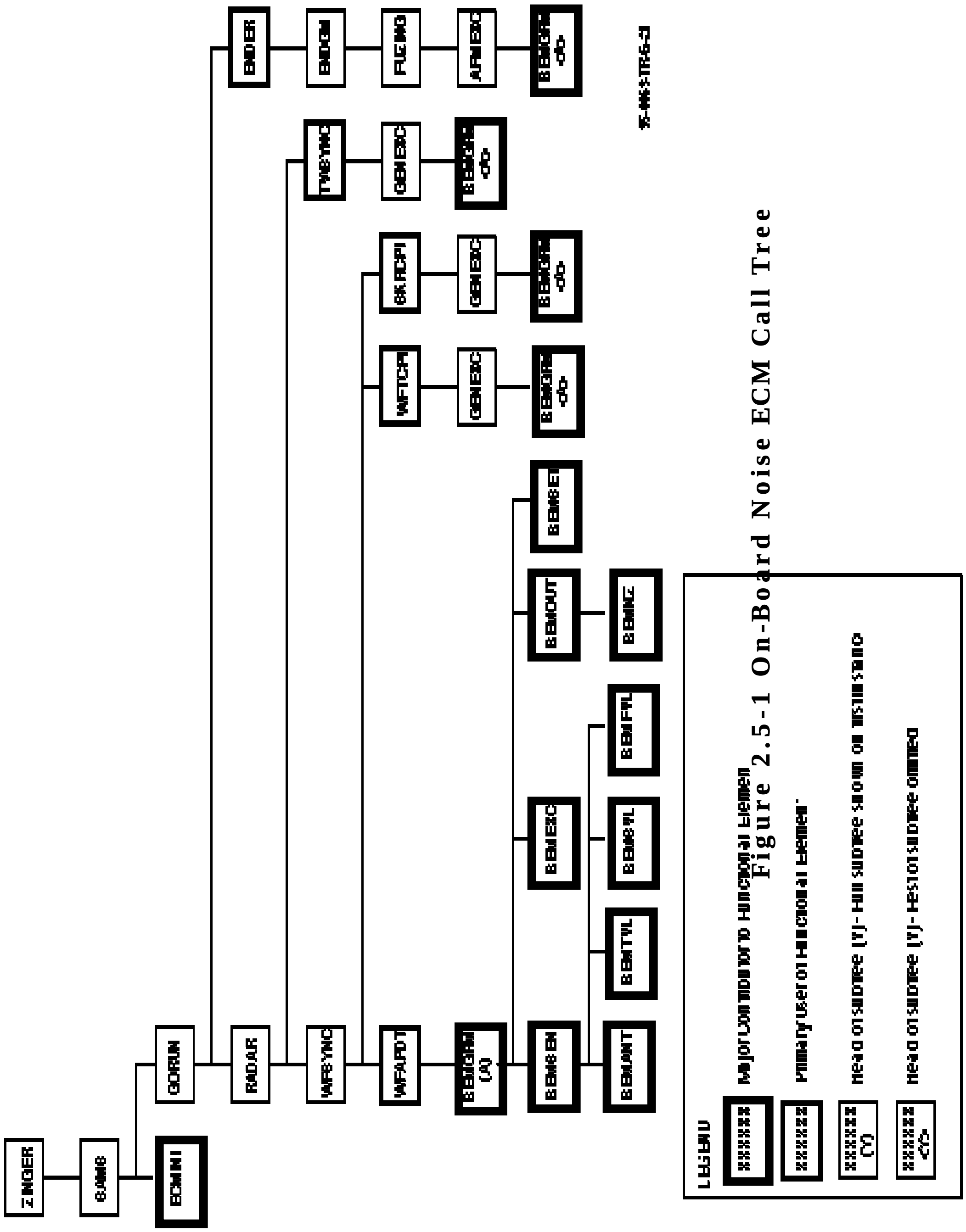


Figure 2.5-1 On-Board Noise ECM Call Tree

FIGURE 2.5-1. On-Board Noise ECM Call Tree.

Figure 2.5-1 shows that there are five different paths to reach the top level routine for the ECM calculations in ESAMS. This routine is BEMGRM, and it may be reached through the following: SKRCPI, WFTCPI, WFAPDT, TWSYNC, and ENDER. SKRCPI provides access to missile seeker code, WFTCPI is the entry to the ground radar tracking calculations for the waveform timed systems (2 and 3 channel monopulse), WFAPDT hooks in to the ground radar acquisition calculations for the waveform timed systems, TWSYNC handles the time stepped systems (track-while-scan), and finally, ENDER brings in the fuzing code and the impact that jamming might have on the missile fuze.

For the waveform timed systems, acquisition (WFAPDT) can be implemented through a fixed threshold or CFAR methodology. If the fixed threshold is employed, WFADP calls FTACQ; however, for CFAR systems, WFADP calls WCFAR. For TWS systems, missile seekers, or missile fuzes, only fixed thresholds are used, and target acquisition could be impacted through calling BEMNZ to inject continuous (i.e. barrage) noise.

For the tracking modes of the fire control radars and the missile seekers, noise jamming (either continuous or SSN) is injected through the GENEXC subroutine. GENEXC calls the individual signal generators which develop the following individual signals: target return, multipath and clutter, thermal noise, and ECM. As shown in Figure 2.5-1, GENEXC activates jamming through a call to BEMGRM.

TABLE 2.5-1. On Board Noise ECM Subroutine Descriptions.

MODULE NAME	DESCRIPTION
BEMGRM	Checks each technique in the ECMD file to see if it is active at the current time against the current radar. Serves as top level routine for ECM calculations
BEMSEN	Sets up engagement features between the jamming aircraft and the ground radar, missile seeker, or the missile fuze.
BEMTVL	Calculates relative geometries and orientations between the ground radar and jamming aircraft.
BEMSVL	Calculates relative geometries and orientations between the missile seeker and jamming aircraft.
BEMFVL	Calculates relative geometries and orientations between the missile fuze and jamming aircraft. Obtains fuze characteristics.
BEMANT	Provides jamming antenna position, velocity, and orientation.
BEMEXC	Loads the current ECM characteristics. These include doppler, power, phase, polarization, pulse width, and time delay.
BEMOUT	Develops the ECM induced voltage to the victim radar receiver for bin masking and SSN.
BEMNZ	Computes the noise-like jamming signals for continuous noise ECM.

Functional Flow Diagram for ECM On-Board Noise

Figure 2.5-2 shows the top-level logical flow of the on-board noise ECM implementation. It includes the functional flow for all of the jamming techniques: continuous noise, bin masking, and SSN. Subroutine names appear in the parentheses at the bottom of each process block. The numbered blocks are described below.

Block 1. The radar mode to jam is extracted from the ECMD file. It can be any (TECMOD=0), the acquisition mode (TECMOD=1), the track mode (TECMOD=2), or jamming to commence after the missile is fired (TECMOD=3).

Block 2. Relative or absolute is set for the various jamming characteristics based on the setting of the "ROA" parameter in the ECMD file. Relative is with respect to the victim radar waveform, while absolute means it is independent of the victim waveform. If the "ROA" parameter is set to one, the value of the characteristic is absolute. If it is zero, the values are relative. For example, DLYROA equal one means that the time delay of the jam signal is absolute. The jamming characteristics set to absolute or relative are frequency, amplitude, phase, polarization, pulse width, and time delay.

Block 3. Environmental values are obtained for the ground radar, missile seeker, or missile fuze by calling BEMTVL, BEMSVL, or BEMFVL, respectively.

Blocks 4, 5 and 6. Relative geometry and orientation between the victim sensor and the jamming aircraft are obtained. This data sets the stage for calculations in blocks 8, 9, and 10.

Block 7. Special calls are made to the fuzing logic to obtain key parameter such as fuze power.

Blocks 8, 9, and 10. The elements of the RADVLU array that are filled are: Doppler due to TX and jammer aircraft velocity; power returned to the jamming aircraft; phase at the jamming aircraft due to TX and aircraft separation; received power from the victim radar at the aircraft (includes victim sensor and jammer antenna attenuation); pulse width of victim radar transmitter; relative closing velocity between the victim sensor and the jamming aircraft; victim receiver voltage gains in the direction of the jamming aircraft for the sum, azimuth difference, and elevation difference channels respectively; and target RCS in the direction of the victim sensor.

Blocks 11, 12, and 13. The end result of these blocks is to provide the ECM waveform. Block 12 is necessary in the alternate route flow to set the jam on-time to zero if it is not specified base on the threat mode. The ECM waveform parameters—either relative or absolute depending on the "ROA" parameters—are Doppler, power, phase, polarization, pulse width, and time delay.

Block 14. The number of techniques is specified in the ECMD file. As illustrated earlier, the bin masking jamming treated the jamming in the individual range gates and Doppler bins as a technique. Thus, there were twelve jamming techniques specified, and the jamming power for each of the techniques must be added to the sum of the power of the previous techniques.

Blocks 15, 16, and 17. The parameter ANTSEL in the ECMD file selects either an omni-directional antenna (ANTSEL .GT.0) or a specific antenna with a specific pattern (ANTSEL .LE.0). If the antenna is omni-directional, the orientation of the jamming aircraft and victim sensor is not important. For the latter case, the jamming antenna which is pointed most directly at the victim sensor is determined. The antenna's location in inertial coordinates is obtained and, at a later time, its gain in the direction of the victim sensor is established.

Block 18. The jammer antenna inertial coordinates with respect to the victim sensor are obtained.

Block 19. Special signals are transferred to the ESAMS bus. These include victim sensor wavelength, loss factors, and antenna error slopes.

Block 20. The call to BEMOUT generates the sum and difference channel complex voltages, apparent range, and Doppler shift of the jamming signal at the victim sensor. The signal has been attenuated appropriately for the transmitter and receiver antenna gains.

Blocks 21, 22, and 23. These blocks show that bin masking and SSN are generated using the same code but that continuous noise is treated differently. With the first two, the noise voltages are obtained in a deterministic fashion using the radar range equation and other pertinent features such as transmitter and receiver gains. Since these two jamming techniques are played in a repeater mode, this methodology is reasonable.

Continuous noise is not used in a repeater, or relative jamming, fashion. Instead, it is employed in an absolute fashion and developed as a noise-like signal. The amplitude of the signal in each section is a stochastic variable, giving a noise-like representation.

Block 24. Since the jamming is developed for the different techniques and also in sections of the PRI for the continuous noise, a check is made and power reduced if necessary, to insure that the power available is not exceeded.

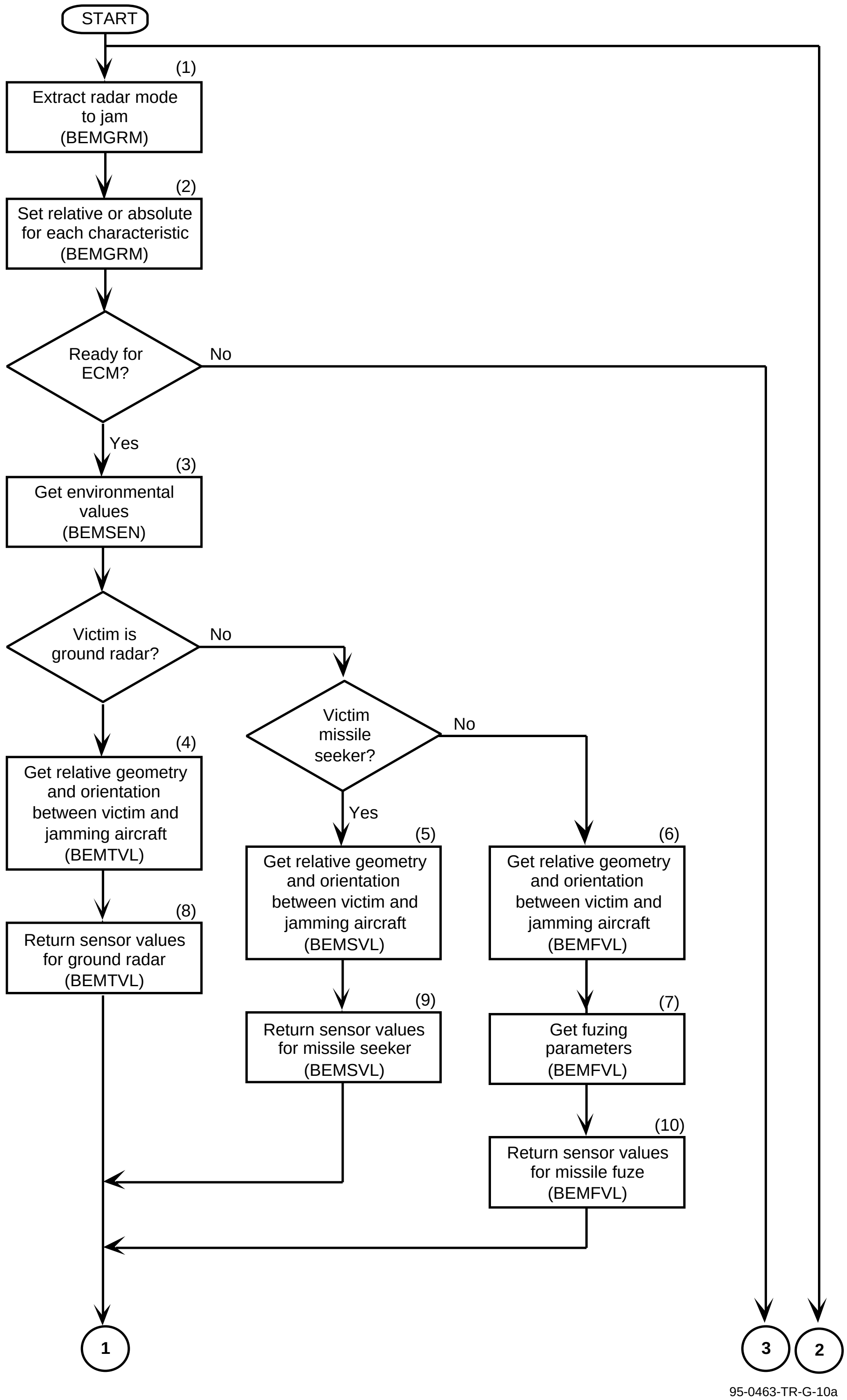


FIGURE 2.5-2. On-Board Noise ECM Functional Flow Diagram.

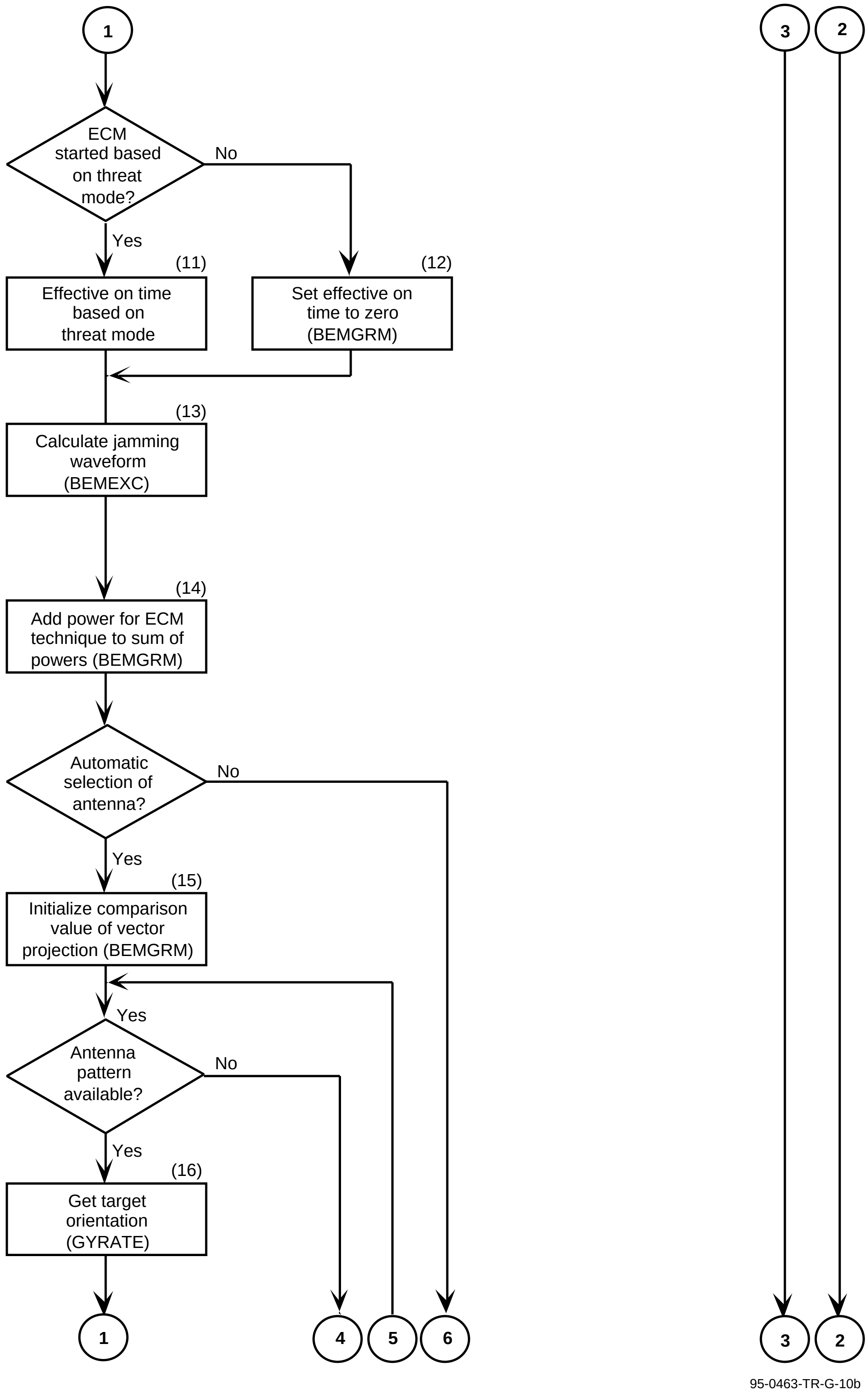


FIGURE 2.5-2. On-Board Noise ECM Functional Flow Diagram. (Contd.)

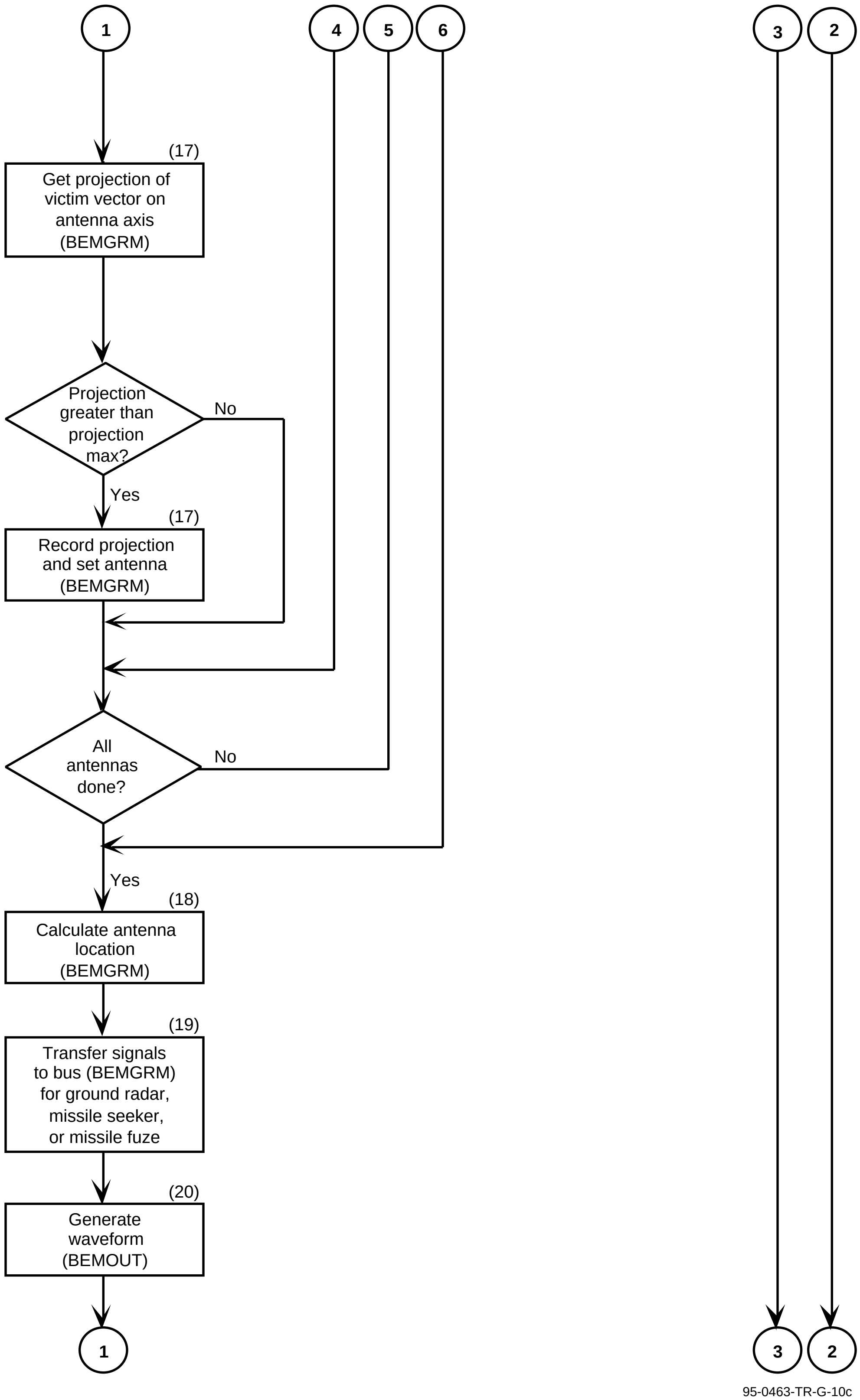


FIGURE 2.5-2. On-Board Noise ECM Functional Flow Diagram. (Contd.)

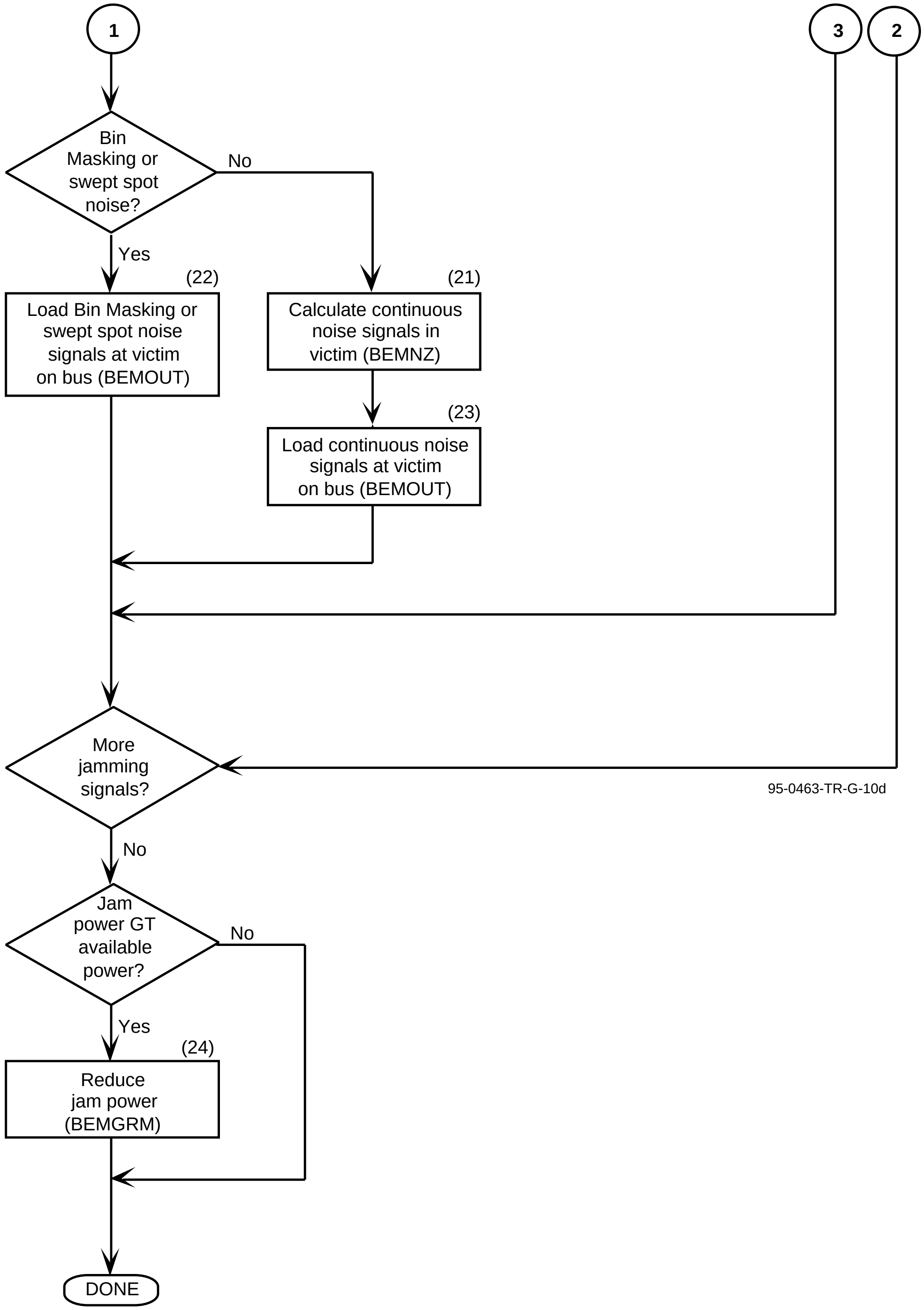


FIGURE 2.5-2. On-Board Noise ECM Functional Flow Diagram. (Contd.)

Subroutine Flow Charts

The logical implementation details of the on-board noise ECM Functional Flow are shown in Figures 2.5-3a through j. The higher level routines which call the ECM algorithms and interface their output (jamming signal voltages) with routines that determine impact on acquisition and tracking are not diagrammed here. This is due to the fact that they are diagrammed in the other VSDR documents which deal with their specific functional performance such as Threshold [28] and Waveform Generator [29]. However, some appropriate comments are made here to explain how the jamming is introduced into acquisition and tracking determination.

There are five different areas in ESAMS which can be impacted by ECM: (1) Waveform driven ground radars during acquisition; (2) waveform driven ground radars during tracking; (3) time stepped TWS radars during acquisition and track; (4) missile seeker operation; (5) and missile fuzing.

The waveform driven ground radars use WFAPDT, WFADP, WCFAR, and FTACQ. WFAPDT implements the acquisition mode detection logic for this model. Based on the RDRD data file variable XINPRC, it implements one of the following modes: Doppler only search, range only search, Doppler followed by range search, and Doppler range simultaneous search. If there are not multiple Doppler bins and range gates to be searched, then WFAPDT specifies that a fixed threshold will be used.

WFAPDT calls WFADP with the information as to whether a fixed or cell averaging CFAR is used. WFAPDT calculates the fixed threshold level and passes it to WFADP. Since WFAPDT has previously called BEMGRM, it passes jam energy information to WFADP.

If a fixed threshold is used, WFADP calls FTACQ. FTACQ determines if there is enough power—including that from the jammer—to exceed the threshold. If there is, the detection flag is set to one. As mentioned previously, the jamming could cause a strobe rather than a blip. In this case, the model resolves as best it can to obtain data to launch the missile (see [28]).

If a CFAR mask is used, WFADP calls WFCFAR to establish the threshold, which is dependent on whether or not Bin Masking is employed. WFCFAR samples specified bins, and the detection threshold is set as a function of probability of false alarm, number of cells sampled, and the noise from the sampled cells.

Subroutines SKRCPI and WFTCPI interface with jamming code through the subroutine GENEXC. SKRCPI and WFTCPI are the Coherent Processing Interval (CPI) code for the seeker and ground radar tracking mode respectively. The CPI code is the lowest level of processing, followed by sequence and group processing. Sequence processing, for example, keeps a running total of angle, range, and Doppler errors plus the number of errors accumulated. The Group level then averages the data and furnishes this information to the appropriate subroutines so that angle, range, and Doppler "gates" are repositioned.

Subroutine SKRCPI also has some ECCM that would be appropriate to noise jamming. Some of the seeker systems have a surge detector. The presence of this detector is identified by the following parameters in the RDRD file:

SRGWIN—Surge detector filter time constant
THRSHS—Surge detection threshold
SRGFCT—Minimum time after track for surge declaration

If a surge detector is specified, then SKRCPI calls HOJCHK to determine if home-on-jam should be implemented. The HOJCHK subroutine checks voltage level signals in the Doppler guard gates to see if the HOJ threshold has been exceeded. If so, the Doppler gate can be frozen, and HOJ tracking implemented.

As mentioned previously, WFTCPI provides interface to the ECM techniques for the waveform driven ground radar tracking. ECCM techniques employed by the ground radar are the following:

1. Range Blanking Pulse. The logic for this technique is contained at the CPI level.
2. Range Gate Repositioning. If selected, this option will reposition the range gate to the position of the guard gate alarm. This logic is contained in subroutine ARGPOA.
3. Range Rate/Doppler Comparisons. This technique is available to any system that tracks Doppler and range gate rate. A check is made of the difference between the range gate rate and the closing rate given by (wavelength*Doppler/2.0). If the difference between these values exceeds the threshold given by RDOTVT, then the comparison alarm is set. Note that the alarm threshold is input in meters per second. This check is disabled if the alarm threshold is zero.
4. Doppler Gate Repositioning. If selected, this option will reposition the Doppler gate as determined by the logic in subroutine AVGPOA.

These techniques are interfaced through a call to subroutine WFTCCM from WFTCPI.

For the time-stepped TWS systems, TWSEC calls GENEXC which in turn calls BEMGRM when ECM is to be employed. Presently, there is no explicit ECCM code for the TWS systems as there is for other ground trackers and the seekers.

Finally, there is the option to introduce jamming into the missile fuze through a call from AFMEXC to BEMGRM. The functional flow diagrams for the on-board noise ECM—starting with BEMGRM—follow.

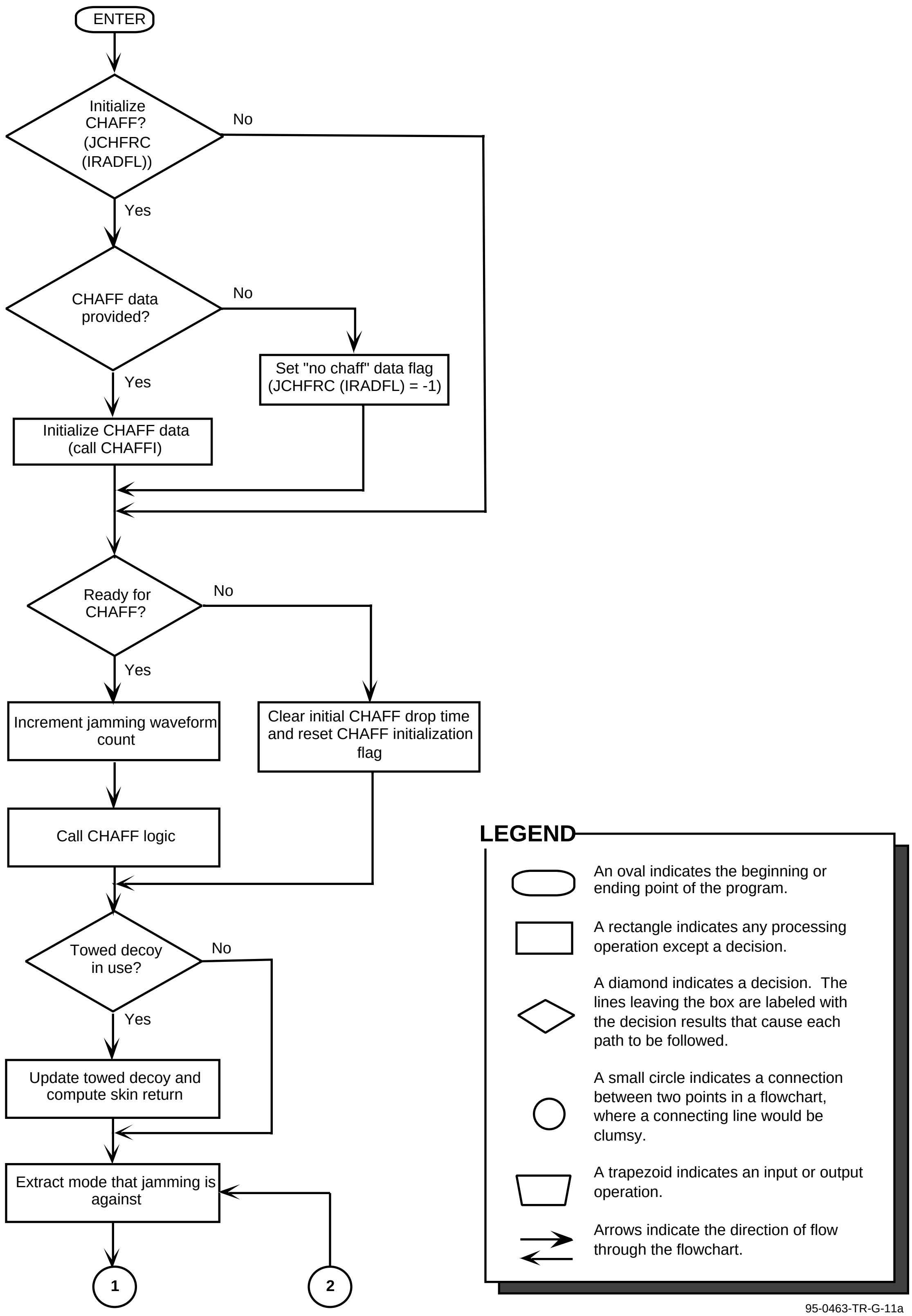


FIGURE 2.5-3a. Functional Flow Diagram for Subroutine BEMGRM.

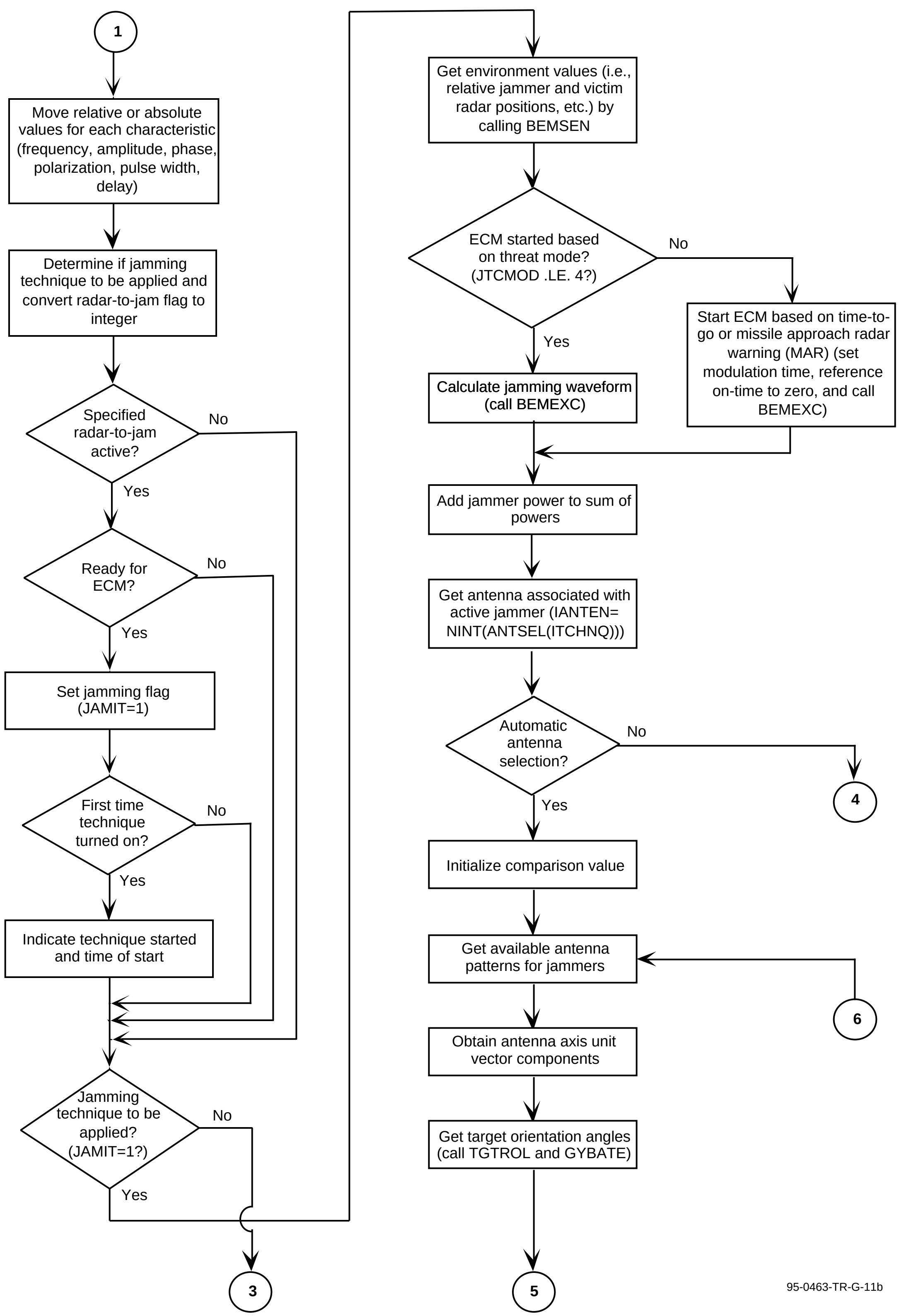


FIGURE 2.5-3a. Functional Flow Diagram for Subroutine BEMGRM. (Contd.)

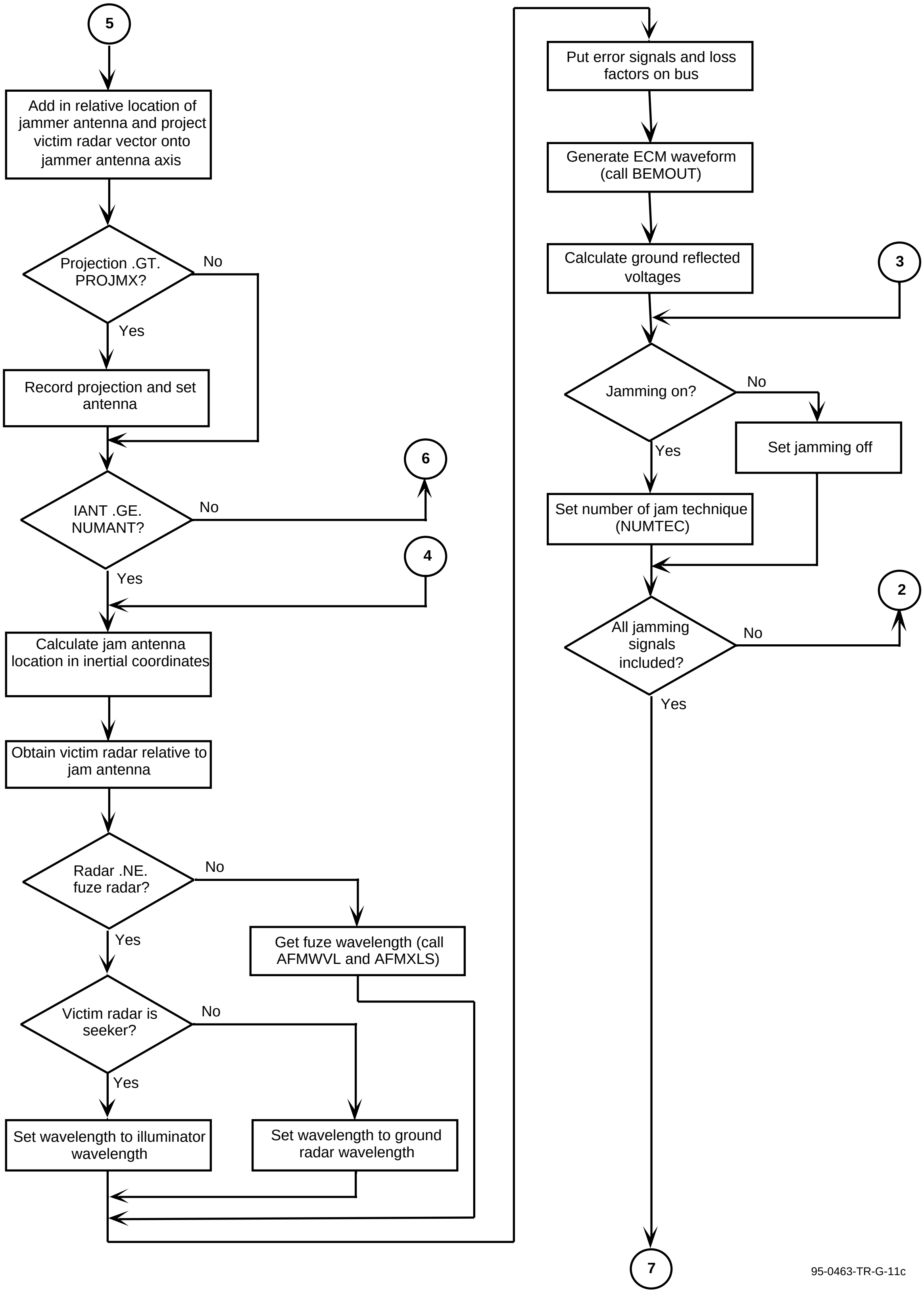


FIGURE 2.5-3a. Functional Flow Diagram for Subroutine BEMGRM. (Contd.)

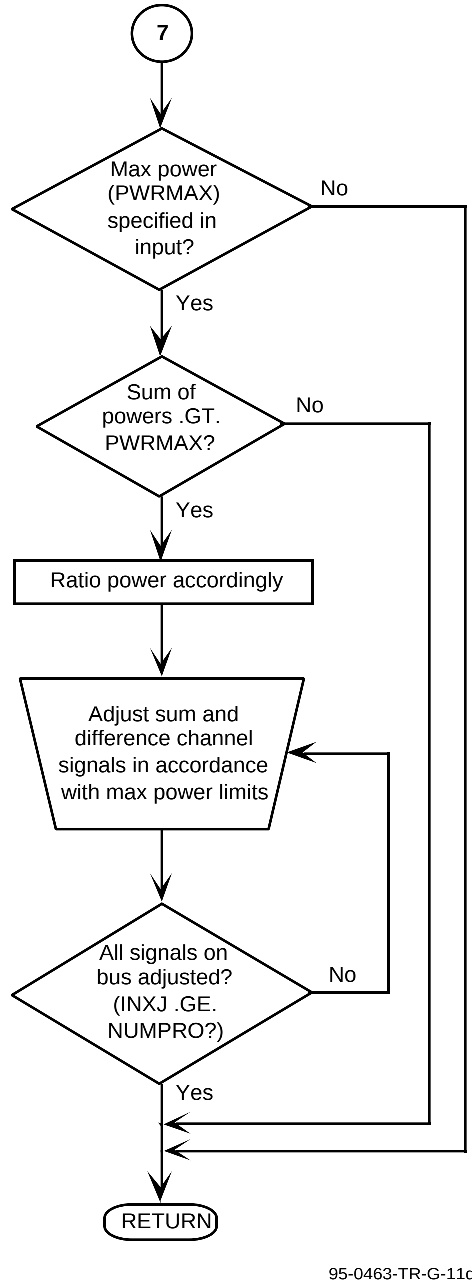


FIGURE 2.5-3a. Functional Flow Diagram for Subroutine BEMGRM. (Contd.)

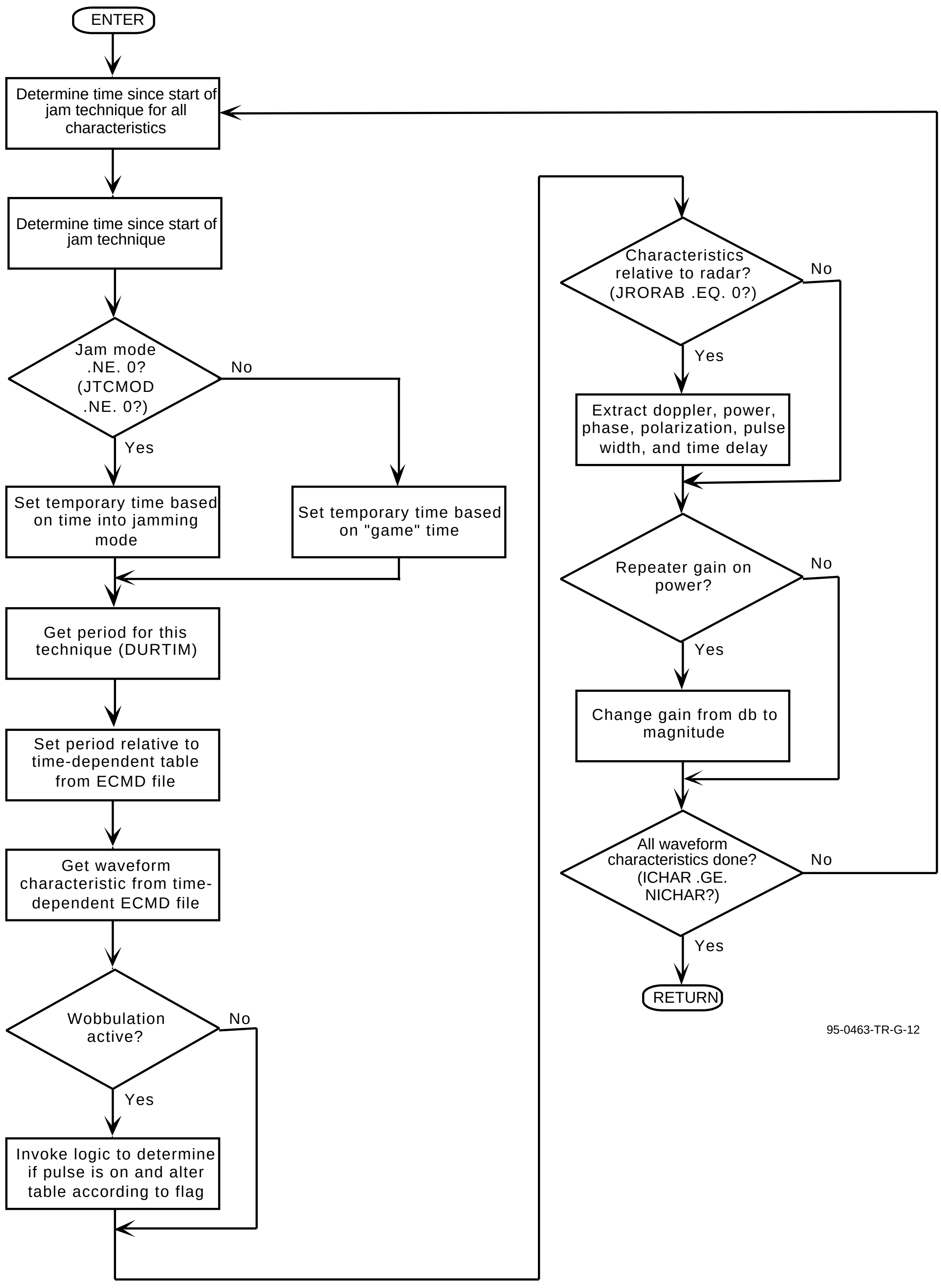


FIGURE 2.5-3b. Functional Flow Diagram for Subroutine BEMEXC.

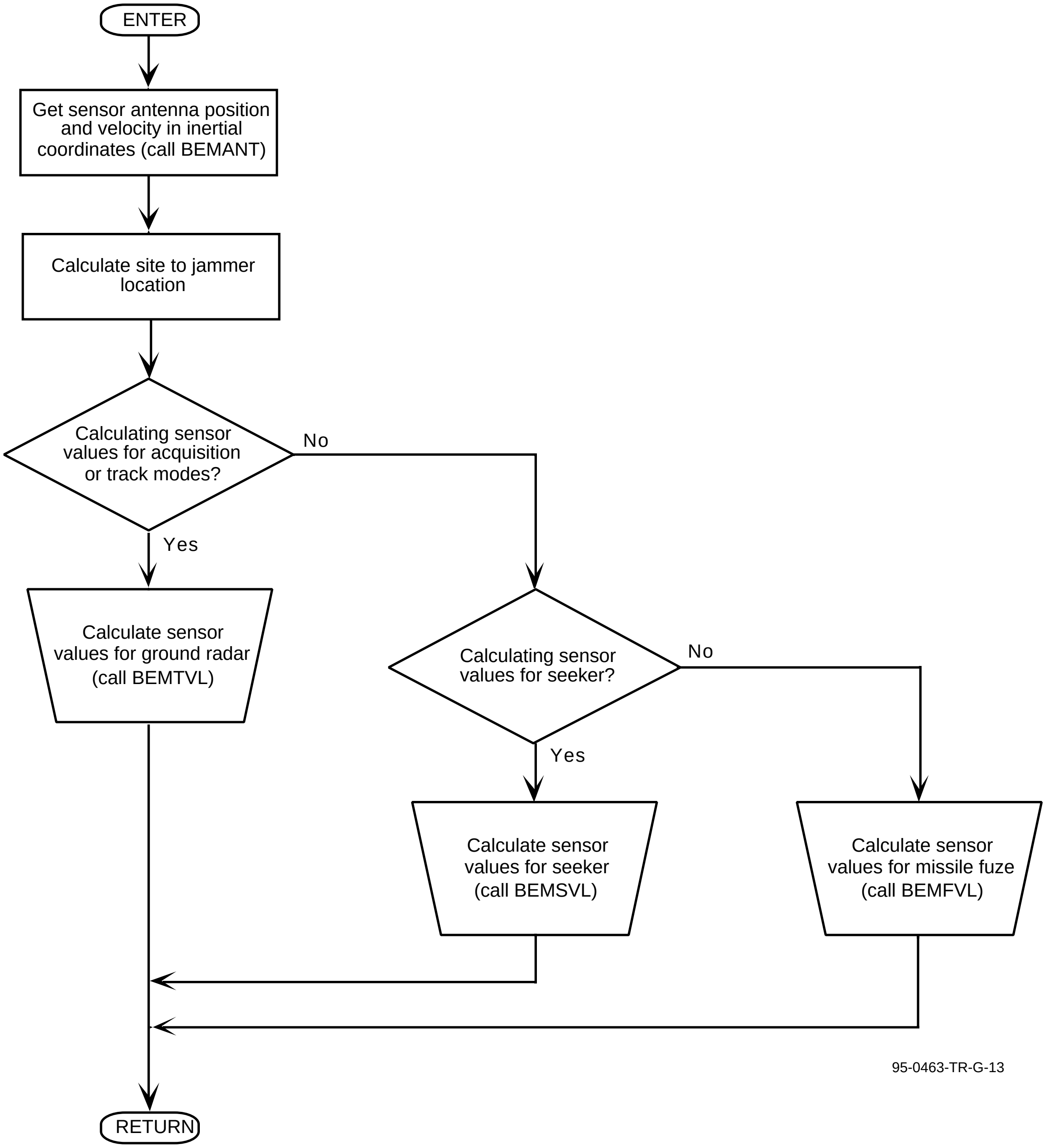


FIGURE 2.5-3c. Functional Flow Diagram for Subroutine BEMSEN.

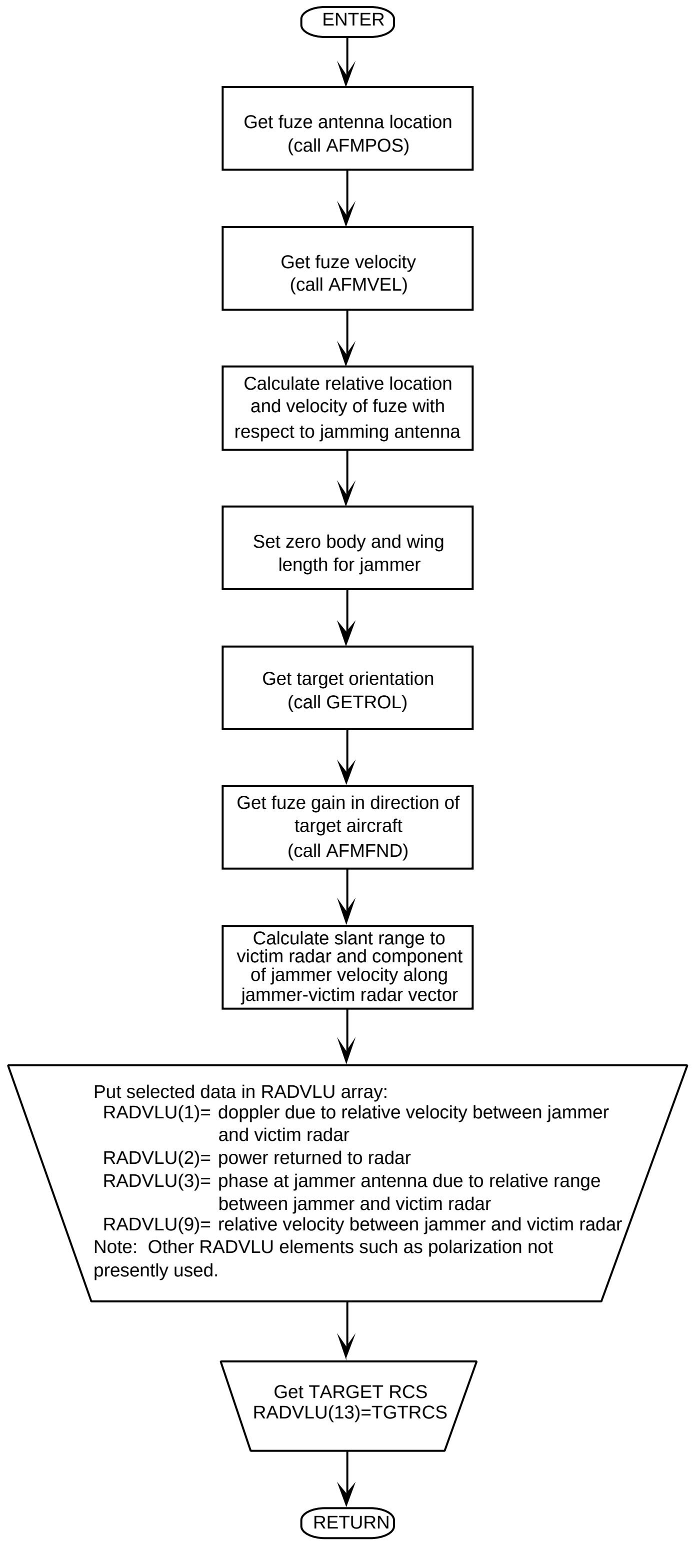


FIGURE 2.5-3d. Functional Flow Diagram for Subroutine BEMFVL.

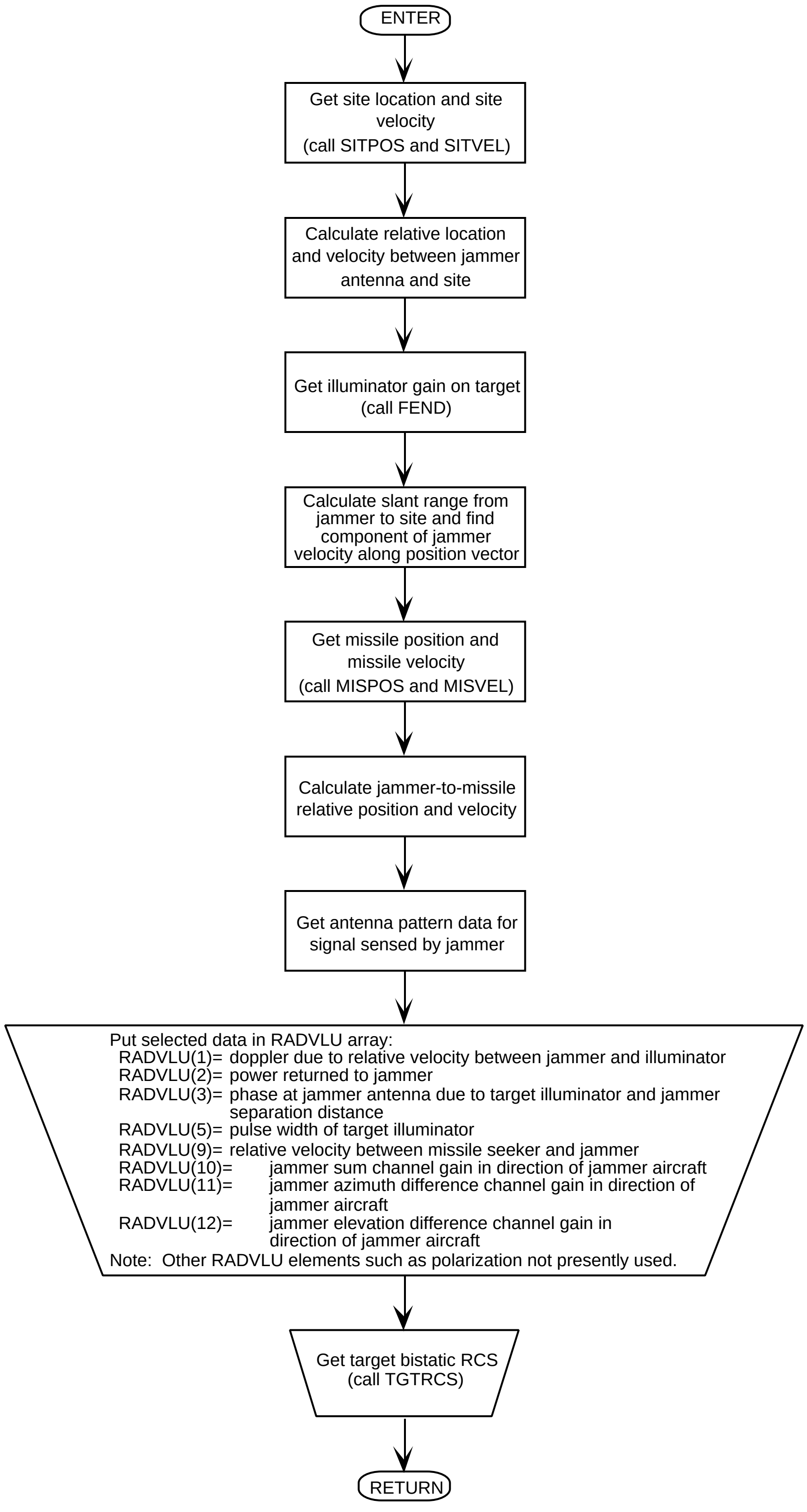


FIGURE 2.5-3e. Functional Flow Diagram for Subroutine BEMSVL.

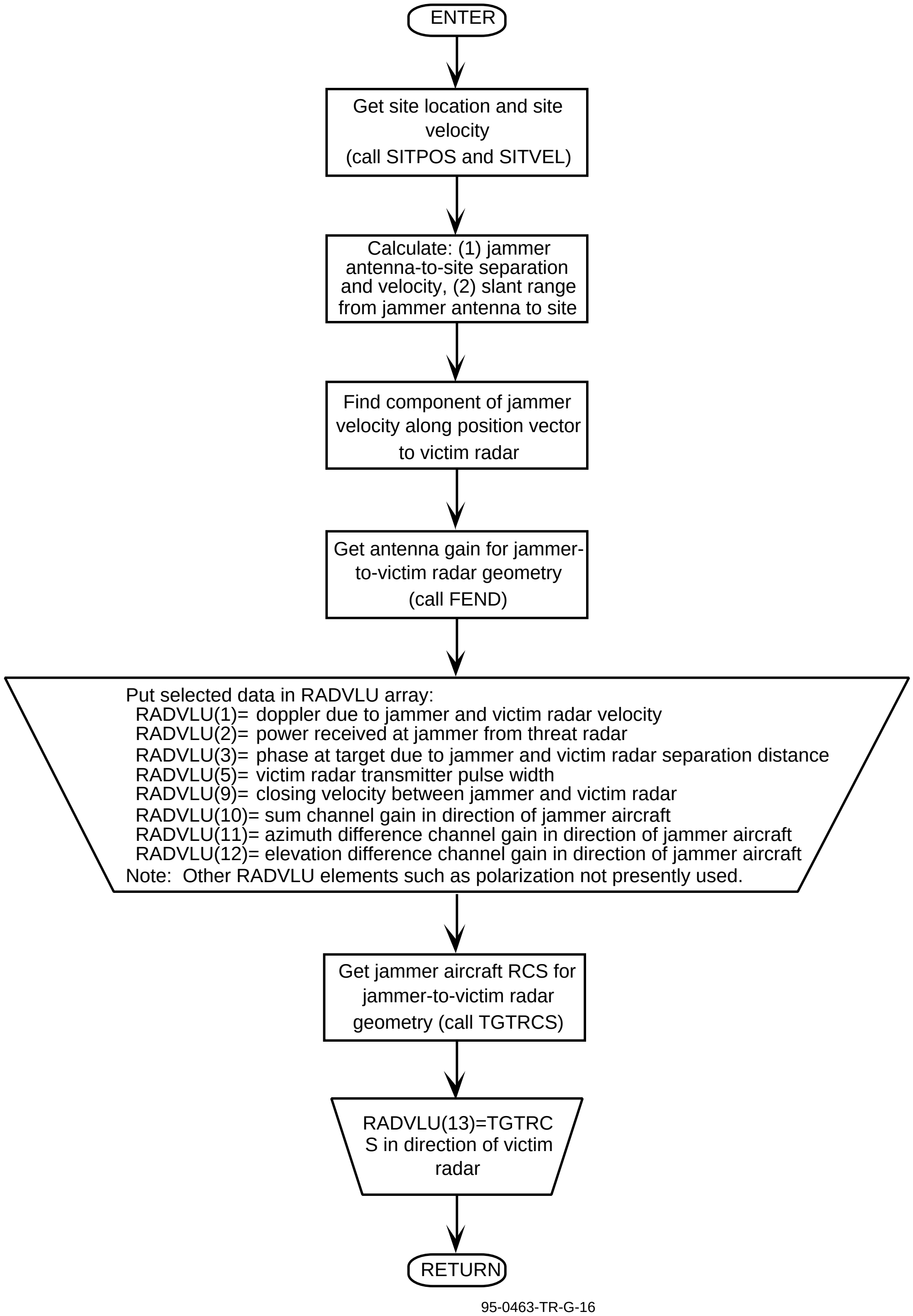


FIGURE 2.5-3f. Functional Flow Diagram for Subroutine BEMTVL.

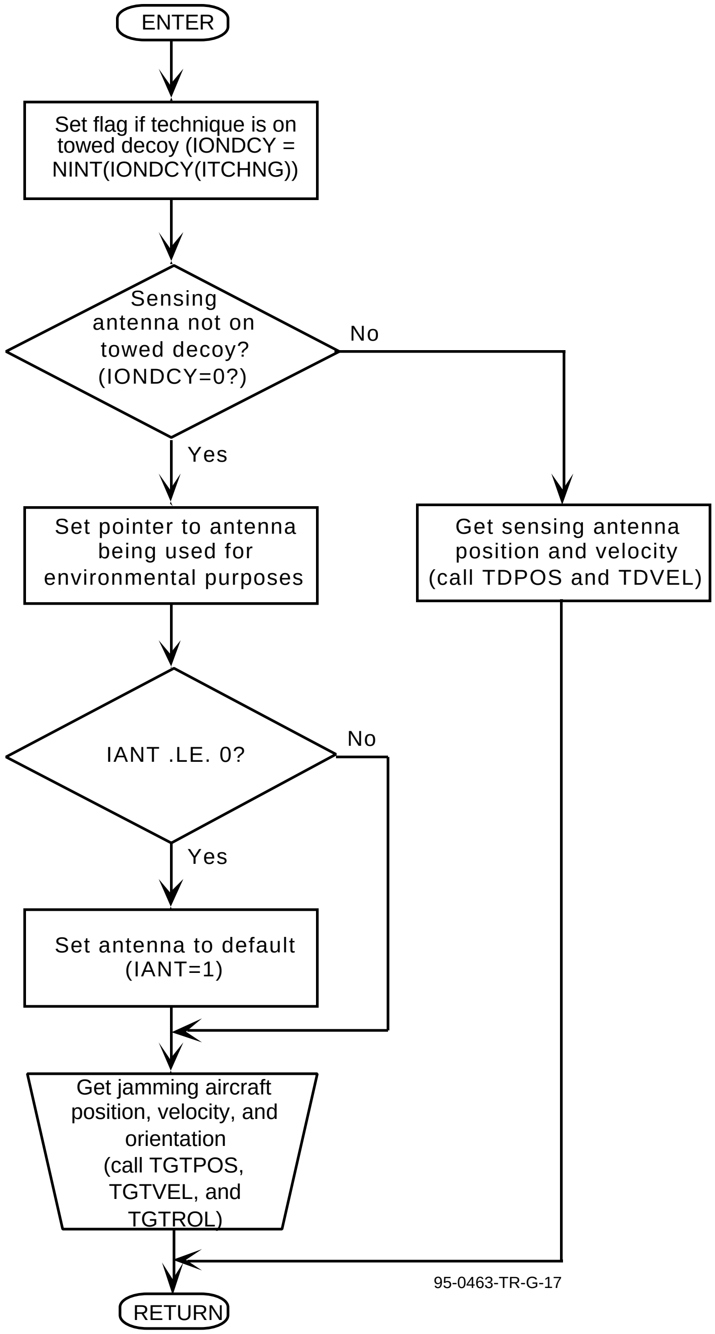


FIGURE 2.5-3g. Functional Flow Diagram for Subroutine BEMANT.

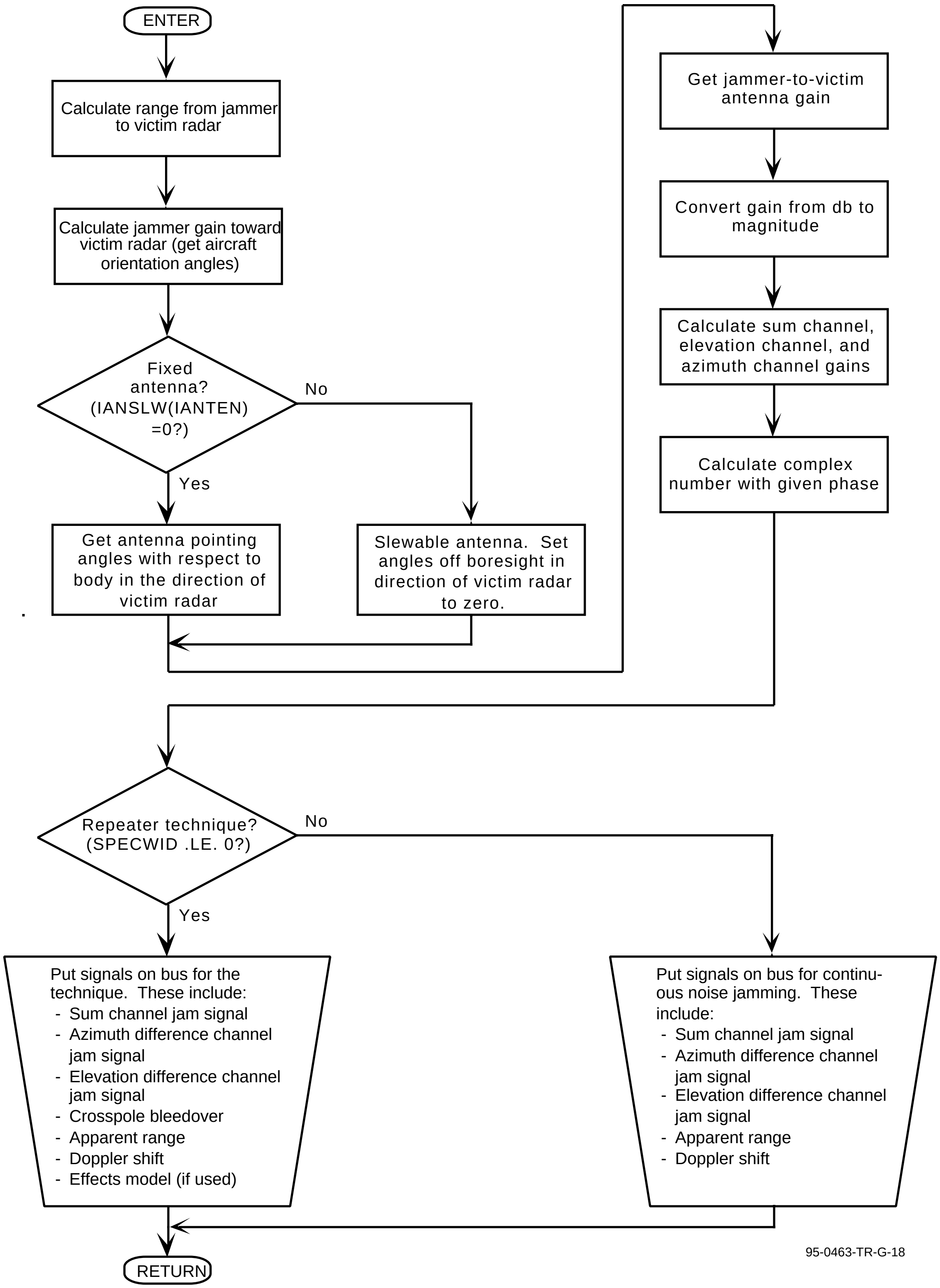


FIGURE 2.5-3h. Functional Flow Diagram for Subroutine BEMOUT.

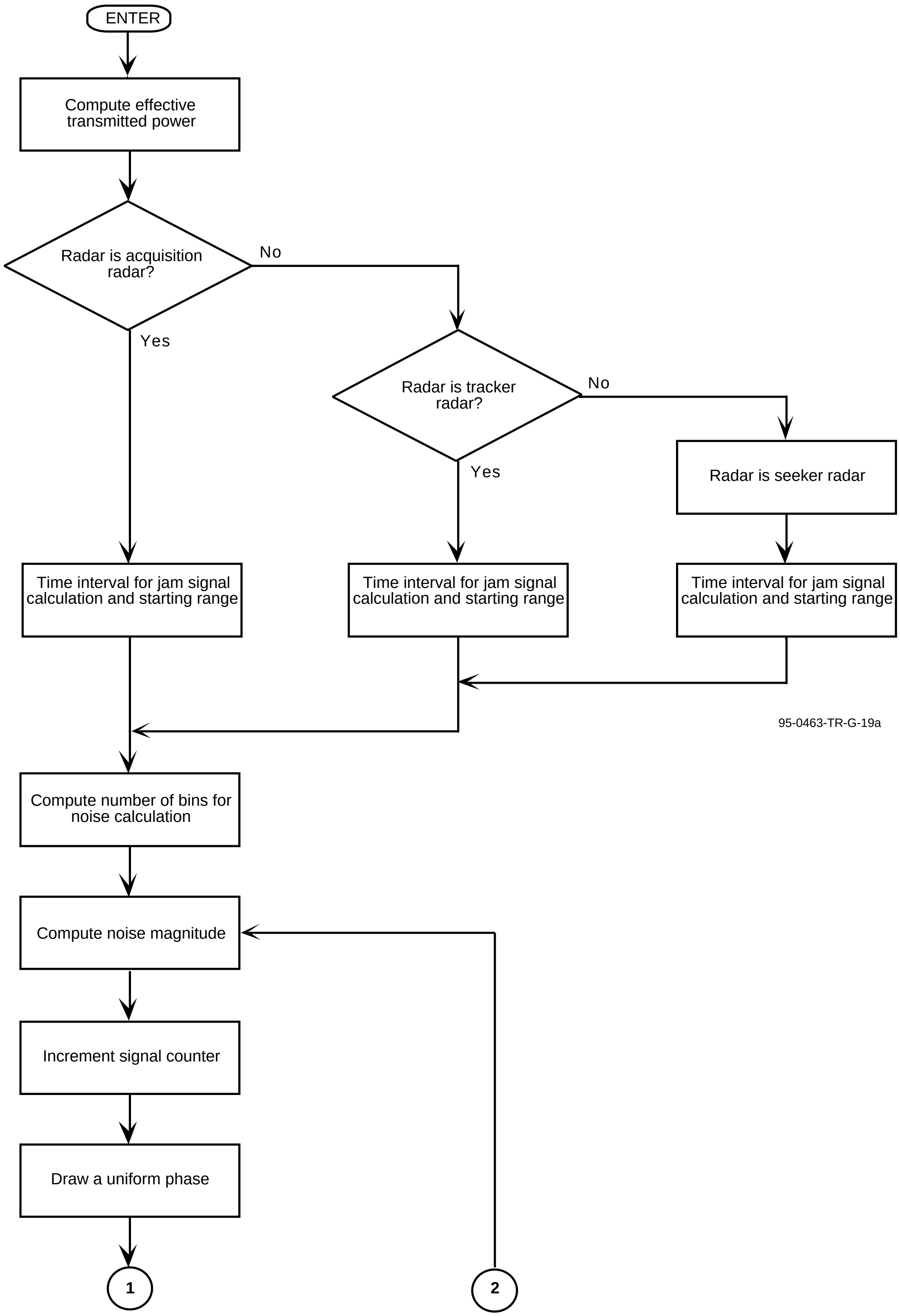


FIGURE 2.5-3i. Functional Flow Diagram for Subroutine BEMNZ.

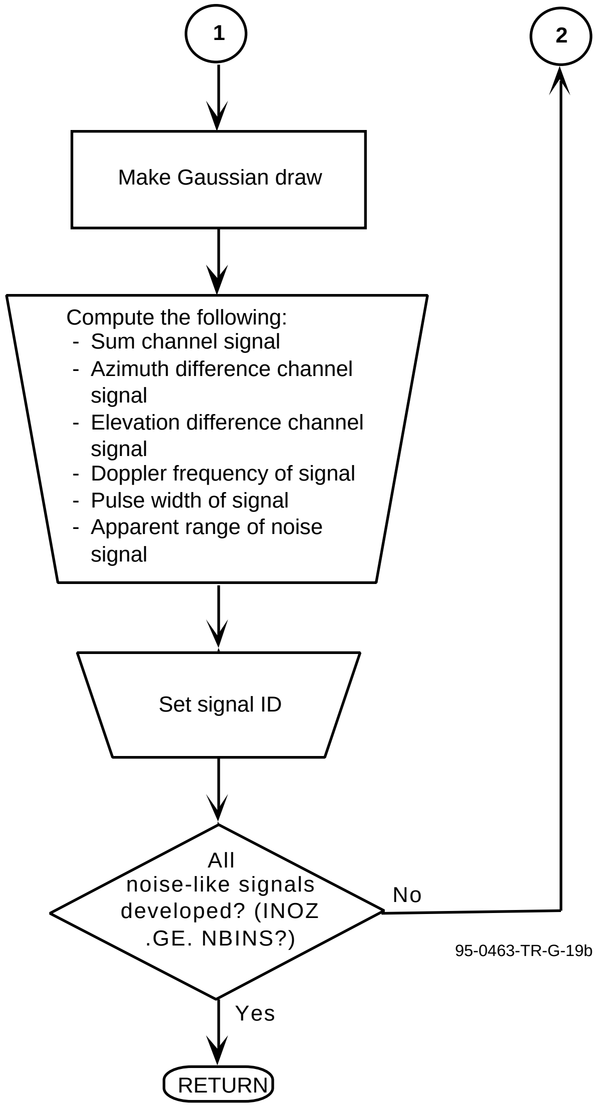
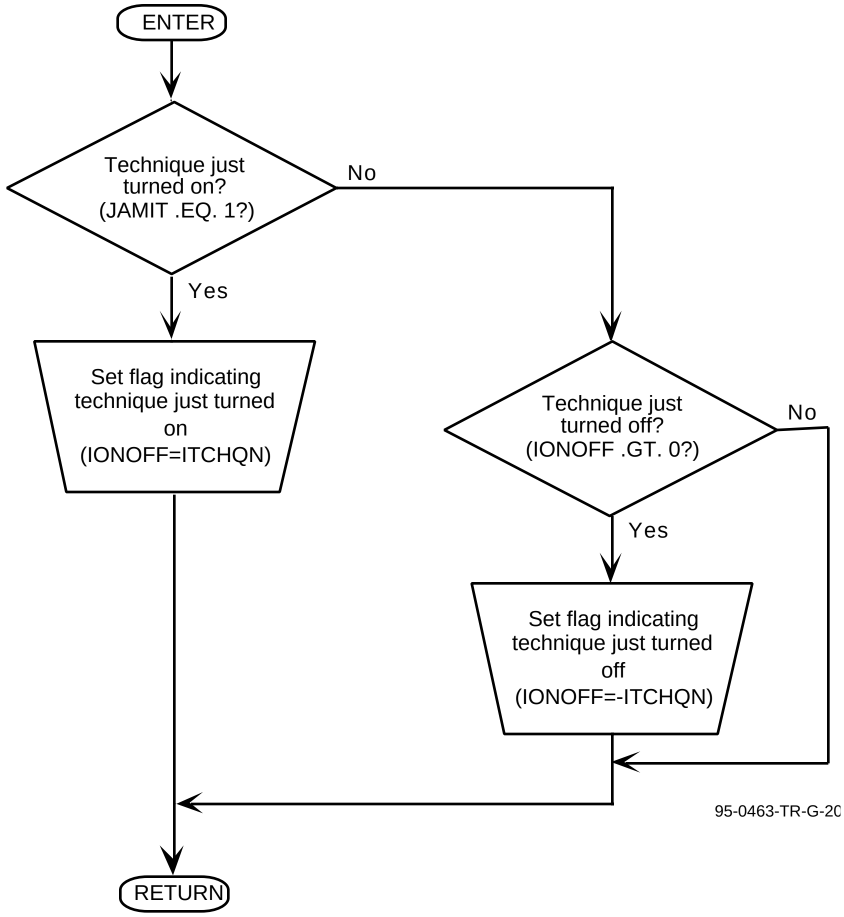


FIGURE 2.5-3i. Functional Flow Diagram for Subroutine BEMNZ. (Contd.)



Note: This subroutine is only used for event message output.

FIGURE 2.5-3j. Functional Flow Diagram for Subroutine BEMSET.

ECM On-Board Noise Inputs and Outputs

The model inputs that affect the ECM On-Board Noise Functional Element are listed in Table 2.5-2.

TABLE 2.5-2. ECM On-Board Noise Model Inputs.

Name	Type	Description
ANSLW(-)	Common ECMD	Flag for whether the antenna is slewable. (=0, fixed; =1, slewable). (Real form) Dimensioned NUMANT (=10).
CHRPT(-,-)	Common ECMD	Pointers to jammer characteristics tables. (Real form) Dimensioned NJCHAR (=6) by NUMTEC (=50).
ECMT(-)	Common ECMD	Workspace array in which jammer tables are kept; pointers locate the tables in ECMT. (Used in ECMINI only for towed decoy.) Dimensioned LECMT (=13757).

TABLE 2.5-2. ECM On-Board Noise Model Inputs. (Contd.)

Name	Type	Description
AMPROA(-)	Common ECMD	Array of flags indicating whether jammer amplitudes are relative or absolute. (=0, relative; otherwise, absolute; =2, case of repeater gain on power) Dimensioned NUMTEC (= 50).
ANTPAZ(-)	Common ECMD	Array of jammer antenna pointing angles in azimuth. Dimensioned NUMANT (=10).
ANTPEL(-)	Common ECMD	Array of jammer antenna pointing angles in elevation. Dimensioned NUMANT (=10).
ANTXLO(-)	Common ECMD	X-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
ANTYLO(-)	Common ECMD	Y-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
ANTZLO(-)	Common ECMD	Z-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
DLYROA(-)	Common ECMD	Array of flags indicating whether jammer time delays are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
DURTIM(-)	Common ECMD	Duration times for jammer techniques. Dimensioned NUMTEC (=50).
FRQROA(-)	Common ECMD	Array of flags indicating whether jammer frequencies are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
PHSROA(-)	Common ECMD	Array of flags indicating whether jammer phases are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
PLSROA(-)	Common ECMD	Array of flags indicating whether jammer pulse widths are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
POLROA(-)	Common ECMD	Array of flags indicating whether jammer polarizations are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
PWRMAX	Common ECMD	Maximum power for jammer.
RADJAM(-)	Common ECMD	Active list of radars. Dimensioned NUMTEC (=50).
SPCWID(-)	Common ECMD	Noise jamming spectral width. Dimensioned NUMTEC (=50).
TECAZB(-)	Common ECMD	Minimum azimuth of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECAZF(-)	Common ECMD	Maximum azimuth of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECHQN	Common ECMD	Number of jammer techniques to be used.

TABLE 2.5-2. ECM On-Board Noise Model Inputs. (Contd.)

Name	Type	Description
TECMOD(-)	Common ECMD	Radar mode to apply jammer technique against. Dimensioned NUMTEC (=50).
TECRMB(-)	Common ECMD	Minimum range of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECRMF(-)	Common ECMD	Minimum range of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TIMEON(-)	Common ECMD	Beginning of time window for jamming by technique. Dimensioned NUMTEC (=50).
TIMOFF(-)	Common ECMD	Ending of time window for jamming by technique. Dimensioned NUMTEC (=50).
XMTPAT(-)	Common ECMD	Jammer transmitter antenna table. Dimensioned LPATRN (=13757).

The outputs of the ECM On-Board Noise Functional Element are jam signals on the signal bus, the count of signals on the bus [NUMPRO] incremented for the added jam signals, and times and flags relating to jammer action; these are listed in Table 2.5-3.

TABLE 2.5-3. ECM On-Board Noise Model Outputs.

Name	Type	Description
IDBUS(-)	Argument	Array of signal ID values [signal bus].
NUMPRO	Argument	Current number of signals on signal processor bus. Incremented from input value by BEMGRM's calls to jammer signal routines.
RTSI(-)	Argument	Array of ranges for signals [signal bus].
SGDOP(-)	Argument	Array of signal Doppler shifts [signal bus].
SGDVA(-)	Argument	Array of complex azimuth-differential channel signal voltages [signal bus.].
SGDVE(-)	Argument	Array of complex elevation-differential channel signal voltages [signal bus.].
SGPCBW(-)	Argument	Array of signal pulse compression bandwidths [signal bus].
SGPW(-)	Argument	Array of signal pulse widths [signal bus].
SGSV(-)	Argument	Array of complex sum channel signal voltages [signal bus.].
STRTED(-)	Common ECMV	Flags indicating that jammer techniques have started. Dimensioned NUMTEC (=50).
TIMMOD(-)	Common ECMV	Times for which system has been in operating modes. Dimensioned NUMMOD (=6).
TSTECH(-)	Common ECMV	Times at which jamming techniques started. Dimensioned NUMTEC (=50).

Inputs and outputs for the subroutines allocated to the implementation of the ECM On-Board Noise functional element follow.

TABLE 2.5-4a. Subroutine ECMINI—Input Data.

Name	Type	Description
ANSLW(-)	Common ECMD	Flag for whether the antenna is slewable. (=0, fixed; =1, slewable). (Real form) Dimensioned NUMANT (=10).
CHRPT(-,-)	Common ECMD	Pointers to jammer characteristics tables. (Real form) Dimensioned NJCHAR (=6) by NUMTEC (=50).
CNTFRQ(-)	Common ECMD	Center frequency for wobbulation generation. Dimensioned NUMTEC (=50).
DUTCYL(-)	Common ECMD	Duty cycle for wobbulation generation. Dimensioned NUMTEC (=50).
ECMT(-)	Common ECMD	Workspace array in which jammer tables are kept; pointers locate the tables in ECMT. (Used in ECMINI only for towed decoy.) Dimensioned LECMT (=13757).
ISPS(5)	Common PROGVI	Fifth element of ISPS(-); here temporarily reset to 1 for input of ECM antenna pattern tables XMTPAT and RCVPAT, then immediately reset to original value. (No actual impact on ECM functionality.)
IWARN	PARAMETER (Include CONST)	Symbolic value for warning-level of error severity. (Initialized to 0.)
LPATRN	PARAMETER (Include ECMD)	Dimension for ECM antenna pattern table arrays, XMTPAT and RCVPAT. (Initialized to 13757.)
LUNLP	Common RUNVI	Logical unit number for “lineprinter” output.
NJCHAR	PARAMETER (Include PARAM)	Maximum number of jammer characteristics that can be used with each technique. (Initialized to 6.)
NUMANT	PARAMETER (Include PARAM)	Maximum number of ECM antennas that can be used. (Initialized to 10.)
NUMMOD	PARAMETER (Include ARYBND)	Maximum number of different operating beam modes. (Initialized to 6.)
NUMTEC	PARAMETER (Include PARAM)	Maximum number of ECM techniques that can be used. (Initialized to 50.)
OFFFRQ(-)	Common ECMD	Offset frequency for wobbulation generation. Dimensioned NUMTEC (=50).
PANT(-)	Common ECMD	Pointer to ATJ jammer antenna table. (Real form) Dimensioned NUMANT (=10).
RMPTIM(-)	Common ECMD	Ramp time for wobbulation generation (time required for wobbulation sweep). Dimensioned NUMTEC (=50).
SWPTYP(-)	Common ECMD	Sweep type index for wobbulation generation. Dimensioned NUMTEC (=50).
XDCYTI	Common ECMD	Scenario time to deploy towed decoy.
XDCYTT	Common ECMD	Time to go to deploy towed decoy.
XDISMA	Common ECMD	Maximum distance between towed decoy and target.
XDPLRA	Common ECMD	Deployment rate for towed decoy.
XTDAZ	Common ECMD	Azimuth with respect to target for deployed towed decoy.
XTDEL	Common ECMD	Elevation with respect to target for deployed towed decoy.
XTDSIG	Common ECMD	Pointer to towed decoy signature table. (Real form)

TABLE 2.5-4b. Subroutine ECMINI—Output Data.

Name	Type	Description
IANSLW(-)	Common ECMI	Flag for whether the antenna is slewable. (=0, fixed; =1, slewable.) (Integer form) Dimensioned NUMANT (=10).
ICHRPT(-,-)	Common ECMI	Pointers to jammer characteristics tables. (Integer form) Dimensioned NJCHAR (=6) by NUMTEC (=50).
IPANT(-)	Common ECMI	Pointer to AJT jammer antenna table. (Integer form) Dimensioned NUMANT (=10).
ISPS(5)	Common PROGVI	Fifth element of ISPS(-); here temporarily reset to 1 for input of ECM antenna pattern tables XMTPAT and RCVPAT, then immediately reset to original value. (No actual impact on ECM functionality.)
JTOWED	Common ECMI	Flag indicating towed decoy in use. (=0, not in use; π0, in use.)

TABLE 2.5-5a. Subroutine BEMGRM—Input Data.

Name	Type	Description
AMPROA(-)	Common ECMD	Array of flags indicating whether jammer amplitudes are relative or absolute. (=0, relative; otherwise, absolute; =2, case of repeater gain on power) Dimensioned NUMTEC (= 50).
ANTPAZ(-)	Common ECMD	Array of jammer antenna pointing angles in azimuth. Dimensioned NUMANT (=10).
ANTPEL(-)	Common ECMD	Array of jammer antenna pointing angles in elevation. Dimensioned NUMANT (=10).
ANTXLO(-)	Common ECMD	X-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
ANTYLO(-)	Common ECMD	Y-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
ANTZLO(-)	Common ECMD	Z-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
CHFILL(-)	Common ECMD	Flags for illuminate chaff option. Dimensioned NUMTEC (=50).
DLYROA(-)	Common ECMD	Array of flags indicating whether jammer time delays are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
DURTIM(-)	Common ECMD	Duration times for jammer techniques. Dimensioned NUMTEC (=50).
ECMT(-)	Common ECMD	Workspace array for jammer tables. Dimensioned LECMT (=13757).
ERCNAZ(-)	Common FREND	Error conversion azimuth—response to angle. Dimensioned MRADFL (=4).
ERCNEL(-)	Common FREND	Error conversion elevation—response to angle. Dimensioned MRADFL (=4).
FRQROA(-)	Common ECMD	Array of flags indicating whether jammer frequencies are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).

TABLE 2.5-5a. Subroutine BEMGRM—Input Data. (Contd.)

Name	Type	Description
IANSLW(-)	Common ECMI	Flags indicating whether jammer antennas are fixed or slewable. (=0, fixed; =1, slewable) (Integer form) Dimensioned NUMANT (=10).
ICHRPT(-)	Common ECMI	Pointers to jammer characteristics tables (in ECMT). (Integer form) Dimensioned NJCHAR (=6).
IONOFF(-)	Common ECMI	On/off flags for jammer techniques. Dimensioned NUMTEC (=50).
IPANT(-)	Common ECMI	Pointers to jammer antenna pattern tables (in ECMT). (Integer form) Dimensioned NUMANT (=10).
IRADFL	Common FLAGS	Identifying index of current radar in use.
IXPNT1	Common ECMI	First dimension index from previous two-dimensional table lookup.
IXPNT2	Common ECMI	Second dimension index from previous two-dimensional table lookup.
JTOWED	Common ECMI	Flag indicating whether towed decoy is in use.
KB2I	PARAMETER Include CONST	Flag indicating transformation from body to inertial coordinates in call of GYRATE. Initialized to 2.
KFREQ	PARAMETER Include PARAM	Pointer corresponding to frequency as a jammer characteristic. Initialized to 1.
KPARC	Common ECMI	Number of chaff parcels in the air.
KPHASE	PARAMETER Include PARAM	Pointer corresponding to PHASE as a jammer characteristic. Initialized to 3.
KPWR	PARAMETER Include PARAM	Pointer corresponding to power as a jammer characteristic. Initialized to 2.
KTDEL	PARAMETER Include PARAM	Pointer corresponding to time delay as a jammer characteristic. Initialized to 6.
NJCHAR	PARAMETER Include PARAM	Maximum number of jammer characteristics. Initialized to 6.
NRCHAR	PARAMETER Include ARYBND	Maximum number of radar characteristics. Initialized to 13.
NUMANT	PARAMETER Include PARAM	Maximum number of jammer antennas. Initialized to 10.
NUMPRO	Argument	Current number of signals on signal processor bus. (Incremented by subroutines invoked by BEMGRM; hence also an output variable.)
PHSROA(-)	Common ECMD	Array of flags indicating whether jammer phases are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
PLSROA(-)	Common ECMD	Array of flags indicating whether jammer pulse widths are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
POLROA(-)	Common ECMD	Array of flags indicating whether jammer polarizations are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).

TABLE 2.5-5a. Subroutine BEMGRM—Input Data. (Contd.)

Name	Type	Description
PTRFDG	Common ECMD	Pointer to effects array.
PWRMAX	Common ECMD	Maximum power for jammer.
RADCHF	Common ECMD	Flag indicating whether chaff is used.
RADJAM(-)	Common ECMD	Active list of radars. Dimensioned NUMTEC (=50).
RTM	Common MSLTGT	Range between target and missile.
RTMDOT	Common MSLTGT	Range rate between target and missile.
SPCWID(-)	Common ECMD	Noise jamming spectral width. Dimensioned NUMTEC (=50).
SWPTYP(-)	Common ECMD	Sweep type index for wobbulation generation. Dimensioned NUMTEC (=50).
TECAZB(-)	Common ECMD	Minimum azimuth of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECAZF(-)	Common ECMD	Maximum azimuth of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECHQN	Common ECMD	Number of jammer techniques to be used.
TECMOD(-)	Common ECMD	Radar mode to apply jammer technique against. Dimensioned NUMTEC (=50).
TECRMB(-)	Common ECMD	Minimum range of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECRMF(-)	Common ECMD	Minimum range of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TIMEG	Common GRADAR	Running simulation time.
TIMEON(-)	Common ECMD	Beginning of time window for jamming by technique. Dimensioned NUMTEC (=50).
TIMOFF(-)	Common ECMD	Ending of time window for jamming by technique. Dimensioned NUMTEC (=50).
WVLTX(-)	Common GRADAR	Radar wavelength. Dimensioned MRADFL (=4).
XLOSS(-)	Common GRADAR	Radar correction loss factor. Dimensioned MRADFL (=4).
XMTPAT(-)	Common ECMD	Jammer transmitter antenna table. Dimensioned LPATRN (=13757).
XV	Argument	X-component of victim location in inertial coordinates.
XVDOT	Argument	X-component of victim velocity in inertial coordinates.
YV	Argument	Y-component of victim location in inertial coordinates.
YVDOT	Argument	Y-component of victim velocity in inertial coordinates.
ZV	Argument	Z-component of victim location in inertial coordinates.
ZVDOT	Argument	Z-component of victim velocity in inertial coordinates.

TABLE 2.5-5b. Subroutine BEMGRM—Output Data.

Name	Type	Description
IDBUS(-)	Argument	Array of signal ID values [signal bus].
NUMPRO	Argument	Current number of signals on signal processor bus. Incremented from input value by BEMGRM’s calls to jammer signal routines.
RTSI(-)	Argument	Array of ranges for signals [signal bus].
SGDOP(-)	Argument	Array of signal Doppler shifts [signal bus].
SGDVA(-)	Argument	Array of complex azimuth-differential channel signal voltages [signal bus.].
SGDVE(-)	Argument	Array of complex elevation-differential channel signal voltages [signal bus.].
SGPCBW(-)	Argument	Array of signal pulse compression bandwidths [signal bus].
SGPW(-)	Argument	Array of signal pulse widths [signal bus].
SGSV(-)	Argument	Array of complex sum channel signal voltages [signal bus.].
STRTED(-)	Common ECMV	Flags indicating that jammer techniques have started. Dimensioned NUMTEC (=50).
TIMMOD(-)	Common ECMV	Times for which system has been in operating modes. Dimensioned NUMMOD (=6).
TSTECH(-)	Common ECMV	Times at which jamming techniques started. Dimensioned NUMTEC (=50).

TABLE 2.5-6a. Subroutine BEMANT—Input Data.

Name	Type	Description
ANTPHI	Return from TDROLL	Jammer sensing antenna Euler angle of orientation, phi. (Via this source for towed decoy only.)
ANTPSI	Return from TDROLL	Jammer sensing antenna Euler angle of orientation, psi. (Via this source for towed decoy only.)
ANTSEN(-)	Common ECMD	Pointer to the antenna being used for environment sensing. Dimensioned NUMTEC (=50).
ANTTHT	Return from TDROLL	Jammer sensing antenna Euler angle of orientation, theta. (Via this source for towed decoy only.)
ANTX	Return from TDPOS	Jammer sensing antenna inertial x-coordinate with respect to target. (Via this source for towed decoy only).
ANTXD	Return from TDVEL	Jammer sensing antenna inertial x-velocity with respect to target. (Via this source for towed decoy only.)
ANTXLO(-)	Common ECMD	X-coordinate of sensing antenna in target body coordinates. Dimensioned NUMANT (=10).
ANTY	Return from TDPOS	Jammer sensing antenna inertial y-coordinate with respect to target. (Via this source for towed decoy only).
ANTYD	Return from TDVEL	Jammer sensing antenna inertial y-velocity with respect to target. (Via this source for towed decoy only.)
ANTYLO(-)	Common ECMD	Y-coordinate of sensing antenna in target body coordinates. Dimensioned NUMANT (=10).

TABLE 2.5-6a. Subroutine BEMANT—Input Data. (Contd.)

Name	Type	Description
ANTZ	Return from TDPOS	Jammer sensing antenna inertial z-coordinate with respect to target. (Via this source for towed decoy only.)
ANTZD	Return from TDVEL	Jammer sensing antenna inertial z-velocity with respect to target. (Via this source for towed decoy only.)
ANTZLO(-)	Common ECMD	Z-coordinate of sensing antenna in target body coordinates. Dimensioned NUMANT (=10).
ITCHNQ	Argument	Number of current technique being used. (Actual argument: ITCHNQ from BEMGRM via BEMSEN.)
ONDCY(-)	Common ECMD	Flag indicating whether this technique is located on the towed decoy. (=0, not on decoy; =1, on decoy) Dimensioned NUMTEC (=50).
TGTPHI	Return from TGTROL	Current Euler angle of orientation of target, phi.
TGTPSI	Return from TGTROL	Current Euler angle of orientation of target, psi.
TGTTHT	Return from TGTROL	Current Euler angle of orientation of target, theta.
TGTX	Return from TGTPOS	Current inertial x-coordinate of target.
TGTXD	Return from TGTVEL	Current inertial x-velocity of target.
TGTY	Return from TGTPOS	Current inertial y-coordinate of target.
TGTYD	Return from TGTVEL	Current inertial y-velocity of target.
TGTZ	Return from TGTPOS	Current inertial z-coordinate of target.
TGTZD	Return from TGTVEL	Current inertial z-velocity of target.
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM via BEMSEN.)

TABLE 2.5-6b. Subroutine BEMANT—Output Data.

Name	Type	Description
ANTPHI	Argument	Jammer sensing antenna Euler angle of orientation, phi. Either computed in BEMANT, or for towed decoy returned by subroutine TDROLL.
ANTPSI	Argument	Jammer sensing antenna Euler angle of orientation, psi. Either computed in BEMANT, or for towed decoy returned by subroutine TDROLL.
ANTTHT	Argument	Jammer sensing antenna Euler angle of orientation, theta. Either computed in BEMANT, or for towed decoy returned by subroutine TDROLL.
ANTX	Argument	Jammer sensing antenna inertial x-coordinate with respect to target. Either computed in BEMANT, or for towed decoy returned by subroutine TDPOS.
ANTXD	Argument	Jammer sensing antenna inertial x-velocity with respect to target. Either computed in BEMANT, or for towed decoy returned by subroutine TDVEL.
ANTY	Argument	Jammer sensing antenna inertial y-coordinate with respect to target. Either computed in BEMANT, or for towed decoy returned by subroutine TDPOS.
ANTYD	Argument	Jammer sensing antenna inertial y-velocity with respect to target. Either computed in BEMANT, or for towed decoy returned by subroutine TDVEL.
ANTZ	Argument	Jammer sensing antenna inertial z-coordinate with respect to target. Either computed in BEMANT, or for towed decoy returned by subroutine TDPOS.
ANTZD	Argument	Jammer sensing antenna inertial z-velocity with respect to target. Either computed in BEMANT, or for towed decoy returned by subroutine TDVEL.

TABLE 2.5-7a. Subroutine BEMTVL—Input Data.

Name	Type	Description
ANTPHI	Argument	Jammer sensing antenna Euler angle of orientation, phi.
ANTPSI	Argument	Jammer sensing antenna Euler angle of orientation, psi.
ANTTHT	Argument	Jammer sensing antenna Euler angle of orientation, theta.
ANTX	Argument	Jammer sensing antenna inertial x-coordinate with respect to target.
ANTXD	Argument	Jammer sensing antenna inertial x-velocity with respect to target.
ANTY	Argument	Jammer sensing antenna inertial y-coordinate with respect to target.
ANTYD	Argument	Jammer sensing antenna inertial y-velocity with respect to target.
ANTZ	Argument	Jammer sensing antenna inertial z-coordinate with respect to target.
ANTZD	Argument	Jammer sensing antenna inertial z-velocity with respect to target.
GDFAZ	Return from FEND	Azimuth difference-channel antenna voltage gain for site radar.
GDFEL	Return from FEND	Elevation difference-channel antenna voltage gain for site radar.
GSUM	Return from FEND	Sum-channel antenna voltage gain for site radar.
IRADFL	Common FLAGS	Current site radar type.
PWRTX(-)	Common GRADAR	Current transmitter power of site radar.
PWTX(-)	Common GRADAR	Current transmitter pulse width of site radar.
RCS	Return from TGTRCS	Radar cross-section of target from site radar.
RGAIN	Return from ANTGAN	Current jammer sense receiver antenna gain toward site radar (magnitude).
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM via BEMSEN.)
WVLTX(-)	Common GRADAR	Current wavelength of site radar.
XSJ	Return from SITPOS	X-component of current victim site location.
XSJD	Return from SITVEL	X-component of current victim site velocity.
YSJ	Return from SITPOS	Y-component of current victim site location.
YSJD	Return from SITVEL	Y-component of current victim site velocity.
ZSJ	Return from SITPOS	Z-component of current victim site location.
ZSJD	Return from SITVEL	Z-component of current victim site velocity.

TABLE 2.5-7b. Subroutine BEMTVL—Output Data.

Name	Type	Description
RADVLU(-)	Argument	Array of tracking radar characteristics. Elements 1,2,3,4,5,9,10,11,12, and 13 are loaded by BEMTVL. Dimensioned NRCHAR (=13).

TABLE 2.5-8a. Subroutine BEMSVL—Input Data.

Name	Type	Description
AMISX	Return from MISPOS	X-component of current missile location.
AMISXD	Return from MISVEL	X-component of current missile velocity.
AMISY	Return from MISPOS	Y-component of current missile location.
AMISYD	Return from MISVEL	Y-component of current missile velocity.
AMISZ	Return from MISPOS	Z-component of current missile location.
AMISZD	Return from MISVEL	Z-component of current missile velocity.
ANTPHI	Argument	Jammer sensing antenna Euler angle of orientation, phi.
ANTPSI	Argument	Jammer sensing antenna Euler angle of orientation, psi.
ANTTHT	Argument	Jammer sensing antenna Euler angle of orientation, theta.
ANTX	Argument	Jammer sensing antenna inertial x-coordinate with respect to target.
ANTXD	Argument	Jammer sensing antenna inertial x-velocity with respect to target.
ANTY	Argument	Jammer sensing antenna inertial y-coordinate with respect to target.
ANTYD	Argument	Jammer sensing antenna inertial y-velocity with respect to target.
ANTZ	Argument	Jammer sensing antenna inertial z-coordinate with respect to target.
ANTZD	Argument	Jammer sensing antenna inertial z-velocity with respect to target.
GDFAZ	Return from FEND	Azimuth difference-channel antenna voltage gain for site radar.
GDFAZI	Return from FEND	Azimuth difference-channel antenna voltage gain for site illuminator radar.
GDFEL	Return from FEND	Elevation difference-channel antenna voltage gain for site radar.
GDFELI	Return from FEND	Elevation difference-channel antenna voltage gain for site illuminator radar.
GILL	Return from FEND	Sum-channel antenna voltage gain for site illuminator radar.
GSUM	Return from FEND	Sum-channel antenna voltage gain for site radar.
IRADFL	Common FLAGS	Current site radar type.
PWRTX(-)	Common GRADAR	Current transmitter power of site radar.
PWTX(-)	Common GRADAR	Current transmitter pulse width of site radar.
RCS	Return from TGTRCS	Radar cross-section of target from site radar.
RGAIN	Return from ANTGAN	Current jammer sense receiver antenna gain toward site radar (magnitude).
TGTX	Return from TGTPOS	X-component of current target location.
TGTY	Return from TGTPOS	Y-component of current target location.
TGTZ	Return from TGTPOS	Z-component of current target location.
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM via BEMSEN.)
WVLTX(-)	Common GRADAR	Current wavelength of site radar.
XSJ	Return from SITPOS	X-component of current victim site location.
XSJD	Return from SITVEL	X-component of current victim site velocity.
YSJ	Return from SITPOS	Y-component of current victim site location.
YSJD	Return from SITVEL	Y-component of current victim site velocity.
ZSJ	Return from SITPOS	Z-component of current victim site location.
ZSJD	Return from SITVEL	Z-component of current victim site velocity.

TABLE 2.5-8b. Subroutine BEMSVL—Output Data.

Name	Type	Description
RADVLU(-)	Argument	Array of tracking radar characteristics. Elements 1,2,3,4,5,9,10,11,12, and 13 are loaded by BEMSVL. Dimensioned NRCHAR (=13).

TABLE 2.5-9a. Subroutine BEMFVL—Input Data.

Name	Type	Description
ANTPHI	Argument	Jammer sensing antenna Euler angle of orientation, phi.
ANTPSI	Argument	Jammer sensing antenna Euler angle of orientation, psi.
ANTTHT	Argument	Jammer sensing antenna Euler angle of orientation, theta.
ANTX	Argument	Jammer sensing antenna inertial x-coordinate with respect to target.
ANTXD	Argument	Jammer sensing antenna inertial x-velocity with respect to target.
ANTY	Argument	Jammer sensing antenna inertial y-coordinate with respect to target.
ANTYD	Argument	Jammer sensing antenna inertial y-velocity with respect to target.
ANTZ	Argument	Jammer sensing antenna inertial z-coordinate with respect to target.
ANTZD	Argument	Jammer sensing antenna inertial z-velocity with respect to target.
FUZX	Return from AFMPOS	X-component of current missile location.
FUZXD	Return from MISVEL	X-component of current missile velocity.
FUZY	Return from AFMPOS	Y-component of current missile location.
FUZYD	Return from MISVEL	Y-component of current missile velocity.
FUZZ	Return from AFMPOS	Z-component of current missile location.
FUZZD	Return from MISVEL	Z-component of current missile velocity.
GAIN	Return from FEND	Sum-channel antenna voltage gain for fuze radar.
GDFAZ	Return from FEND	Azimuth difference-channel antenna voltage gain for fuze radar.
GDFEL	Return from FEND	Elevation difference-channel antenna voltage gain for fuze radar.
IRADFL	Common FLAGS	Current radar type.
PWRFUZ	Return from AFMPWR	Current transmitter power of fuze radar.
RCS	Return from TGTRCS	Radar cross-section of target from fuze radar.
RGAIN	Return from ANTGAN	Current jammer sense receiver antenna gain toward fuze radar (magnitude).
TGTX	Return from TGTPOS	X-component of current target location.
TGTY	Return from TGTPOS	Y-component of current target location.
TGTZ	Return from TGTPOS	Z-component of current target location.
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM via BEMSEN.)
WVLFUZ	Return from AFMWVL	Wavelength of fuze radar.
WVLTX(-)	Common GRADAR	Current wavelength of site illuminator radar.

TABLE 2.5-9b. Subroutine BEMFVL—Output Data.

Name	Type	Description
RADVLU(-)	Argument	Array of tracking radar characteristics. Elements 1,2,3,4,9,10,11,12, and 13 are loaded by BEMFVL. Dimensioned NRCHAR (=13).

TABLE 2.5-10a. Subroutine BEMSEN—Input Data.

Name	Type	Description
ANTPHI	Return from BEMANT	Jammer sensing antenna Euler angle of orientation, phi.
ANTPSI	Return from BEMANT	Jammer sensing antenna Euler angle of orientation, psi.
ANTTHT	Return from BEMANT	Jammer sensing antenna Euler angle of orientation, theta.
ANTX	Return from BEMANT	Jammer sensing antenna inertial x-coordinate with respect to target.
ANTXD	Return from BEMANT	Jammer sensing antenna inertial x-velocity with respect to target.
ANTY	Return from BEMANT	Jammer sensing antenna inertial y-coordinate with respect to target.
ANTYD	Return from BEMANT	Jammer sensing antenna inertial y-velocity with respect to target.
ANTZ	Return from BEMANT	Jammer sensing antenna inertial z-coordinate with respect to target.
ANTZD	Return from BEMANT	Jammer sensing antenna inertial z-velocity with respect to target.
IRADFL	Argument	Current radar type.
ITCHNQ	Argument	Index for current jammer technique in use.
RADVLU(-)	Return from BEMTVL, BEMSVL, or BEMFVL	Array of tracking radar characteristics. Elements 1,2,3,4,5,9,10,11,12, and 13 are loaded by BEMTVL, BEMSVL, or BEMFVL (except BEMFVL does not load element 5). Dimensioned NRCHAR (=13).
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM.)
XV	Argument	X-component of current victim site location.
YV	Argument	Y-component of current victim site location.
ZV	Argument	Z-component of current victim site location.

TABLE 2.5-10b. Subroutine BEMSEN—Output Data.

Name	Type	Description
RADVLU(-)	Argument	Array of tracking radar characteristics. Elements 1,2,3,4,5,9,10,11,12, and 13 are loaded by BEMTVL, BEMFVL, or BEMFVL (except BEMFVL does not load element 5). Dimensioned NRCHAR (=13).
XVJ	Argument	X-component of victim site-to-jammer antenna vector.
YVJ	Argument	Y-component of victim site-to-jammer antenna vector.
ZVJ	Argument	Z-component of victim site-to-jammer antenna vector.

TABLE 2.5-11a. Subroutine BEMEXC—Input Data.

Name	Type	Description
DURTIM(-)	Argument	Duration intervals for jammer techniques. Dimensioned NUMTEC (=50).
ECMT(-)	Argument	Workspace array containing jammer tables. Dimensioned LECMT (=5000).
ICHRPT(-)	Argument	Pointers to jammer characteristics for each technique. Dimensioned NJCHAR (=6) by NUMTEC (=50).
IONFLG	Return from GETWOB	Flag indicating whether the pulse of wobbulation is on. (=0, pulse off; otherwise, pulse on)
IRADFL	Argument	Current radar type.
ITCHNQ	Argument	Index for current jammer technique in use.
JTCMOD	Argument	Index for victim mode which jamming is attacking.
KODROA(-)	Argument	Array of flags indicating whether jamming characteristics are absolute or relative to victim characteristics. (=0, relative; otherwise, absolute) Dimensioned NJCHAR (=6).
NJCHAR	PARAMETER Include PARAM	Maximum number of jammer characteristics per technique. Initialized to 6.
RADVLU(-)	Argument	Array of victim radar characteristics. (Elements 1,2,3,4,5,9,10,11,12, and 13 are loaded by BEMTVL, BEMSVL, or BEMFVL (except BEMFVL does not load element 5).) Dimensioned NRCHAR (=13).
SWPTYP	Argument	Sweep type for current jammer technique. (Actual argument: SWPTYP(ITCHNQ).)
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM.)
TIMEON	Argument	Beginning of time window for jamming by current technique. (Actual argument: TIMEON(ITCHNQ), if JTCMOD < 5; TOND=0.0, otherwise.)
TMODE	Argument	Time for which the system has been in current mode. (Actual argument: TIMMOD(max(1,JTCMOD)).)

TABLE 2.5-11b. Subroutine BEMEXC—Output Data.

Name	Type	Description
VALUE(-)	Argument	Array of jammer characteristics. Dimensioned NJCHAR (=6).

TABLE 2.5-12a. Subroutine BEMNZ—Input Data.

Name	Type	Description
ACHVLT	Argument	Azimuth difference-channel voltage factor.
DOPBW(-)	Common GRADAR	Doppler bandwidth for current radar.
DOPJAM	Argument	Jam signal Doppler shift. (Actual argument: RADVLU(KRVVCL)/WAVLEN; KRVVCL initialized to 9.)
ECHVLT	Argument	Elevation difference-channel voltage factor.
GDRAW	Return from GAUSS	Gaussian random number.
IRADFL	Common FLAGS	Current radar type.
NUMBIN	Common WFADAI (Include WFADAT)	Number of range bins in the range-Doppler matrix.
NUMNZ	PARAMETER Include ARYBND	Maximum number of noise bins for noise calculations. Initialized to 2.
NUMPRO	Argument	Current number of signals on signal processor bus. Will be incremented from input value by BEMNZ.
PWJAM	Argument	Jam signal pulse width. (Actual argument: VALUE(KPWID); KPWID initialized to 5.)
PWRIN	Argument	Jammer power level received in victim sum channel. (Actual argument: SCHVLT**2.)
RGATES(-)	Common GRADAR	Range-gate center for current radar.
RNGWDT	Common WFADAR (Include WFADAT)	Range-width (in time) of a range-bin in range-Doppler matrix for radar acquisition mode.
RSTACQ	Common WFADAR (Include WFADAT)	Starting range for acquisition.
SCHVLT	Argument	Sum-channel voltage factor.
SPCWID	Argument	Noise jamming spectral width. (Actual argument: SPCWID(ITCHNQ) from BEMGRM via BEMOUT.)
TRGW(-)	Common SVOVAR	Range-gate width (in time) for radar tracking mode.

TABLE 2.5-12b. Subroutine BEMNZ—Output Data.

Name	Type	Description
IDBUS(-)	Argument	Array of signal ID values [signal bus].
NUMPRO	Argument	Current number of signals on signal processor bus. Incremented from input value by BEMNZ.
RTSI(-)	Argument	Array of ranges for signals [signal bus].
SGDOP(-)	Argument	Array of signal Doppler shifts [signal bus].

TABLE 2.5-12b. Subroutine BEMNZ—Output Data. (Contd.)

Name	Type	Description
SGDVA(-)	Argument	Array of complex azimuth-differential channel signal voltages [signal bus.].
SGDVE(-)	Argument	Array of complex elevation-differential channel signal voltages [signal bus.].
SGPCBW(-)	Argument	Array of signal pulse compression bandwidths [signal bus].
SGPW(-)	Argument	Array of signal pulse widths [signal bus].
SGSV(-)	Argument	Array of complex sum channel signal voltages [signal bus.].

TABLE 2.5-13a. Subroutine BEMOUT—Input Data.

Name	Type	Description
ANTPAZ(-)	Argument	Antenna pointing angle in azimuth (body axes) for current jammer antenna.
ANTPEL(-)	Argument	Antenna pointing angle in elevation (body axes) for current jammer antenna.
DFJMAZ(-)	Return from BEMNZ or BEMFDG	Array of complex azimuth-differential channel signal voltages [signal bus.].
DFJMEL(-)	Return from BEMNZ or BEMFDG	Array of complex elevation-differential channel signal voltages [signal bus.].
DOPJAM(-)	Return from BEMNZ	Array of signal Doppler shifts [signal bus].
ECMT(-)	Argument	Workspace array containing jammer tables. Dimensioned LECMT (=5000).
ERCNAZ	Argument	Error conversion azimuth—response to angle. (Actual argument: ERAZ.).
ERCNEL	Argument	Error conversion azimuth—response to angle. (Actual argument: EREL.).
GAINJ	Return from TLU2	Jammer antenna gain. (From either XMTPAT or ECMT(IPANT(IANTEN)) tables.)
IANSLW(-)	Argument	Flags indicating whether jammer antennas are fixed or slewable. (=0, fixed; otherwise, slewable.)
IANTEN	Argument	Index for current jammer antenna.
IPANT(-)	Argument	Pointers to jammer antenna pattern tables in ECMT.
IRADFL	Common FLAGS	Current radar type.
ITCHNQ	Argument	Index for current jammer technique.
IXPNT1	Argument	First dimension index from previous two-dimensional table lookup.
IXPNT2	Argument	Second dimension index from previous two-dimensional table lookup.
KODAMP	Argument	Flag indicating whether the jammer amplitude characteristic is relative or absolute. (Actual argument: KODROA(2).)
NUMPRO	Argument; Return from BEMNZ	Current number of signals on signal processor bus. Will be incremented from input value by BEMOUT.
PCBWJM(-)	Return from BEMNZ	Array of signal pulse compression bandwidths [signal bus].
PHIT	Return from TGTROL	Target Euler orientation angle, phi. (Actual argument: PHIBM.)
PSIT	Return from TGTROL	Target Euler orientation angle, psi. (Actual argument: PSIBM.)

TABLE 2.5-13a. Subroutine BEMOUT—Input Data. (Contd.)

Name	Type	Description
PTRFDG	Argument	Pointer to ECM effects logic.
PWJAM(-)	Argument; Return from BEMNZ	Jam signal pulse width [signal bus]. (Actual argument: SIGPW.)
RADVLU(-)	Argument	Array of victim radar characteristics. (Elements 1,2,3,4,5,9,10,11,12, and 13 are loaded by BEMTVL, BEMSVL, or BEMFVL (except BEMFVL does not load element 5).) Dimensioned NRCHAR (=13).
RSJAM(-)	Return from BEMNZ	Array of ranges for signals [signal bus].
SPCWID	Argument	Noise jamming spectral width for current jamming technique. (Actual argument: SPCWID(ITCHNQ).)
SUMJAM(-)	Return from BEMNZ or BEMFDG	Array of complex sum channel signal voltages [signal bus.].
THETAT	Return from TGTROL	Target Euler orientation angle, theta. (Actual argument: THETBM.)
TIMEB	Argument	Running simulation time. (Actual argument: TIMEG from BEMGRM.)
VALUE(-)	Argument	Array of jammer characteristics. Dimensioned NJCHAR (=6).
WAVLEN	Argument	Wavelength of current radar signal.
XLOSS	Argument	Radar correction loss factor for current radar. (actual argument: XLS.)
XMTPAT(-)	Argument	Array containing the ECM transmitter antenna table. Dimensioned LPATRN (=13757).
XVJ	Argument	X-component of victim-to-jammer vector. (Actual argument: XVJA.)
YVJ	Argument	Y-component of victim-to-jammer vector. (Actual argument: YVJA.)
ZVJ	Argument	Z-component of victim-to-jammer vector. (Actual argument: ZVJA.)

TABLE 2.5-13b. Subroutine BEMOUT—Output Data.

Name	Type	Description
DFJMAZ(-)	Argument	Array of complex azimuth-differential channel signal voltages [signal bus.]. (Actual argument: SGDVA.)
DFJMEL(-)	Argument	Array of complex elevation-differential channel signal voltages [signal bus.]. (Actual argument: SGDVE.)
DOPJAM(-)	Argument	Array of signal Doppler shifts [signal bus]. (Actual argument: SGDOP.)
IDBUS(-)	Argument	Array of signal ID values [signal bus].
IXPNT1	Argument	First dimension index from previous two-dimensional table lookup.
IXPNT2	Argument	Second dimension index from previous two-dimensional table lookup.
NUMPRO	Argument	Current number of signals on signal processor bus. Incremented from input value by BEMNZ.
PCBWJM(-)	Argument	Array of signal pulse compression bandwidths [signal bus]. (Actual argument: SGPCBW.)

TABLE 2.5-13b. Subroutine BEMOUT—Output Data. (Contd.)

Name	Type	Description
PHIT	Argument	Target Euler orientation angle, phi. (Actual argument: PHIBM.)
PSIT	Argument	Target Euler orientation angle, psi. (Actual argument: PSIBM.)
PWJAM(-)	Argument	Array of signal pulse widths [signal bus]. (Actual argument: SGPW.)
RSJAM(-)	Argument	Array of ranges for signals [signal bus]. (Actual argument: RTSI.)
SUMJAM(-)	Argument	Array of complex sum channel signal voltages [signal bus.]. (Actual argument: SGSV.)
THETAT	Argument	Target Euler orientation angle, theta. (Actual argument: THETBM.)

TABLE 2.5-14a. Subroutine BEMSET—Input Data.

Name	Type	Description
IONOFF	Argument	On/off flag for jammer techniques, used for printing jammer event reports in ESAMS output. May be modified by BEMSET. (Actual argument: IONOFF(ITCHNQ).)
ITCHNQ	Argument	Index for current jammer technique.
JAMIT	Argument	Flag indicating whether jamming is on for current technique. (=1, jamming on; otherwise, off)

TABLE 2.5-14b. Subroutine BEMSET—Output Data.

Name	Type	Description
IONOFF	Argument	On/off flag for jammer techniques, used for printing jammer event reports in ESAMS output. May be modified by BEMSET. (Actual argument: IONOFF(ITCHNQ).)

2.5.4 Assumptions and Limitations

While the on board noise ECM is played in a reasonable realistic manner, for the ground radar, it is possible that the operator could take some different actions if noise jamming were detected. One option would be to change to optical tracking for those systems having it. For some systems a skilled operator could manually detect, acquire, and track using a jammed radar with degraded capability. Since ESAMS 2.7 does not model the human operator in an integrated fashion, the ESAMS user should run some excursions, such as the optical track mode, to bound the impact due to man-in-the-loop.

ESAMS 2.7 also has a number of ECCM techniques which may be employed by the missile seeker. These will be covered in the tracking VSDRs. The impact of the ECCM techniques against the missile seeker should also be bounded through parametric studies.